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TITLE: UNDERWATER LAUNCHED MISSILE SYSTEM CANISTER DESIGN, [redacted]

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ABSTRACT

(U) The document expands on the canister requirements for an Under-water Launched Missile System (ULMS) as proposed in volume 6 of the 1967 STRAT-X Committee Report. Functional flow, environmental requirements and interfaces are identified. Preliminary design sketches, graphs and calculations for the primary structure and missile suspension systems are summarized. Subsystems are identified and discussed. The feasibility of design and construction of horizontally stowed missile canisters for missiles up to 225,000 pounds is verified. The procedures used are considered applicable to the definition and design of other submarine canister systems.

KEY WORDS

Air Bag Suspension
Broaching
Buoyancy
Canister
Encapsulated Missiles
Missile Canister
Missile Suspension
Ring Stiffened Cylinder
Sea Launched Missiles
Shell Buckling
Submarine Canister
Trajectory of Canister
Transit - Underwater Canister
ULMS Canister
Undersea Canister

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1 INTRODUCTION

(U) In 1967 the STRAT-X panel examined the characteristics of various new strategic missile systems and identified an Underwater Long Range Missile System (ULMS) configuration which resulted in a low cost of deployed payload and which enhanced survivability due to added missile range, hence additional deployment area. (Ref. 1) The deployed missiles were larger than the conventional Polaris/Poseidon missiles and submarine design constraints dictated that they be carried horizontally in externally stowed canisters. IR&D studies by The Boeing Company during 1968 provided a preliminary design for one such submarine and canister. (See Reference 2, Figure 1-1 and Appendix A.)

1.1 SCOPE

(U) This document is the result of the 1969 IR&D effort, and defines performance and environmental requirements and describes the procedure used in arriving at the ULMS canister design. It also identifies canister subsystems and proposes design solutions for those mechanical subsystems considered critical to the feasibility of the canister. The solutions are considered adaptible to other horizontally stowed exterior submarine canisters.

1.2 ACKNOWLEDGEMENTS

(U) Acknowledgement of the help provided in the preparation of this document is gratefully given to the following people:

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R. S. N. Lee	Boeing Flight Technology Staff
Ralph Leistikow	Boeing Structures Technology Staff
Harold A. Morrison (Retired)	Boeing Development Design

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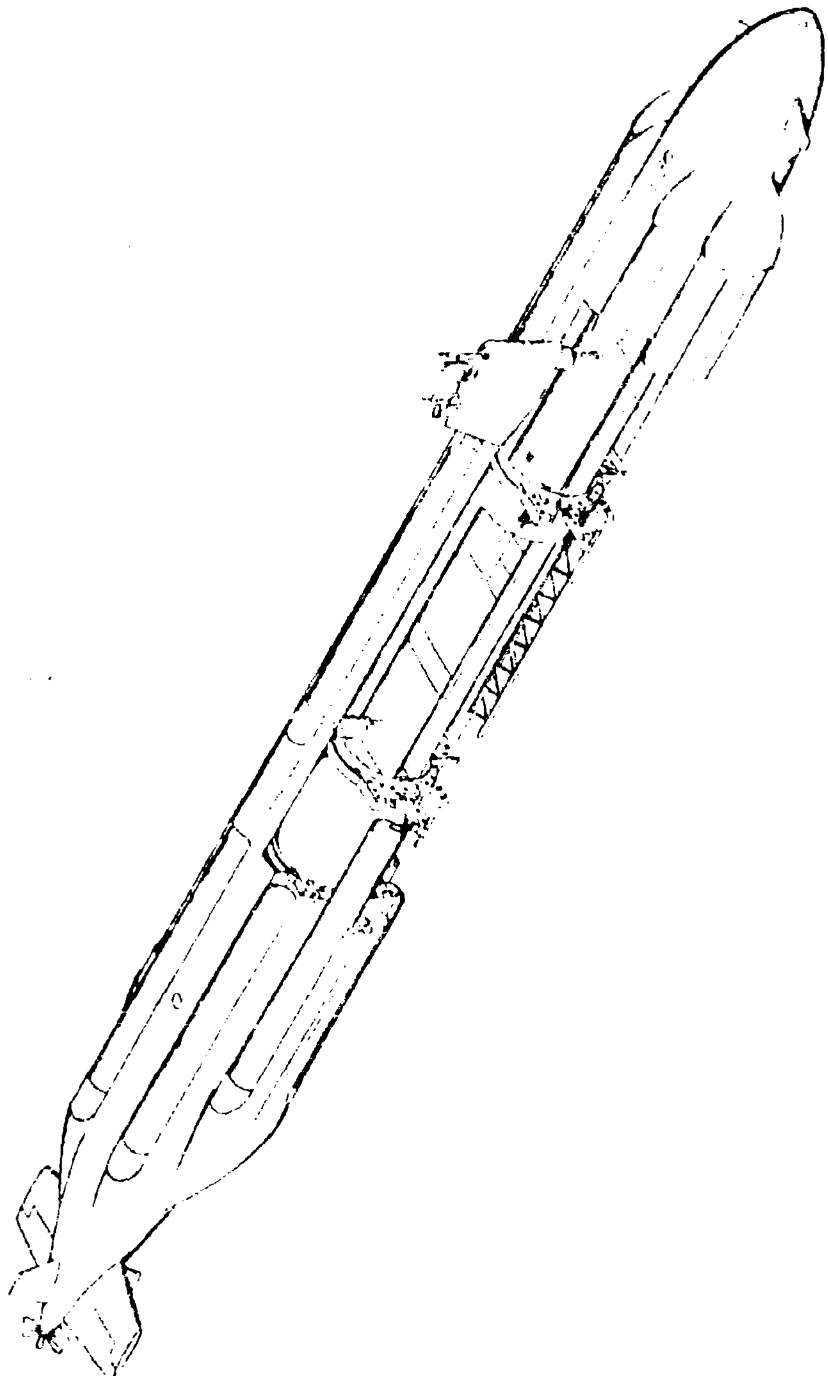


FIGURE 1-1

2.0 SUMMARY

(U) A canister exceeding the performance requirements of the Underwater Launched Missile System (ULMS) as proposed by the STRAT-X Committee report, Volume 6 can be designed and constructed. Requirements for a canister to contain a 225,000 lb. missile 90 inches in diameter and 84.3 feet long to be launched at speeds and depths in excess of present day (1969) Polaris submarine system capabilities have been proposed. A submarine-canisterized system configuration has been conceived and described in Boeing document D2-125971-2 "Preliminary ULMS Submarine Configuration for Horizontal Missile Stowage". See Figure 1.0-1.

(U) Supplemental preliminary design has been accomplished herein to verify the feasibility of the canister.

(U) The canister design proposed is an internally ring stiffened structural shell with dogged lids that open for missile launch at the sea-air interface. The canister is approximately 9.1 feet outside diameter by 92.5 feet long and weighs approximately 130,000 pounds alone and 355,000 pounds with the missile. The canister is carried horizontally on the submarine, supported by a trunnion and latch 3 point suspension system. The missile is supported laterally inside the canister by air bags and restrained longitudinally by a belleville spring system. Integrated electrical, hydraulic, pneumatic, ballast and environmental control systems supplement the structural-mechanical and missile support systems to provide a canister which exceeds the ULMS performance requirements.

(U) Canister release is initiated hydraulically from the submarine and completed by buoyancy and dynamic pressure forces. Positive buoyancy carries the canister to the surface where sensors initiate canister opening and missile launch.

3 REQUIREMENTS

(U) This section outlines the general performance requirements and the design and construction requirements considered for the canister design. Additional definition would be required for a specific ULMS configuration.

3.1 PERFORMANCE REQUIREMENTS

(U) Functional, Operational and Environmental Performance requirements are described in the following paragraphs.

3.1.1 FUNCTIONAL REQUIREMENTS

(U) Figure 3-1 is a chart depicting the canister functional flow.

(U) The primary functions of the Underwater Launched Missile (ULM) canister are as follows:

a. To protect the missile from environmental extremes when at sea.

b. To protect the missile from specified weapons effects when at sea.

c. To transport the missile from the submarine to the surface after release from the submarine.

d. To provide a launch platform for the missile at the sea-air interface.

(U) The secondary functions of the Underwater Launched Missile (ULM) canister include:

e. To provide a missile strongback during handling and transportation.

f. To protect the missile from environmental effects during land operations.

g. To provide interfacing equipment for electrical monitoring and control, locking, safing and release of the missile.

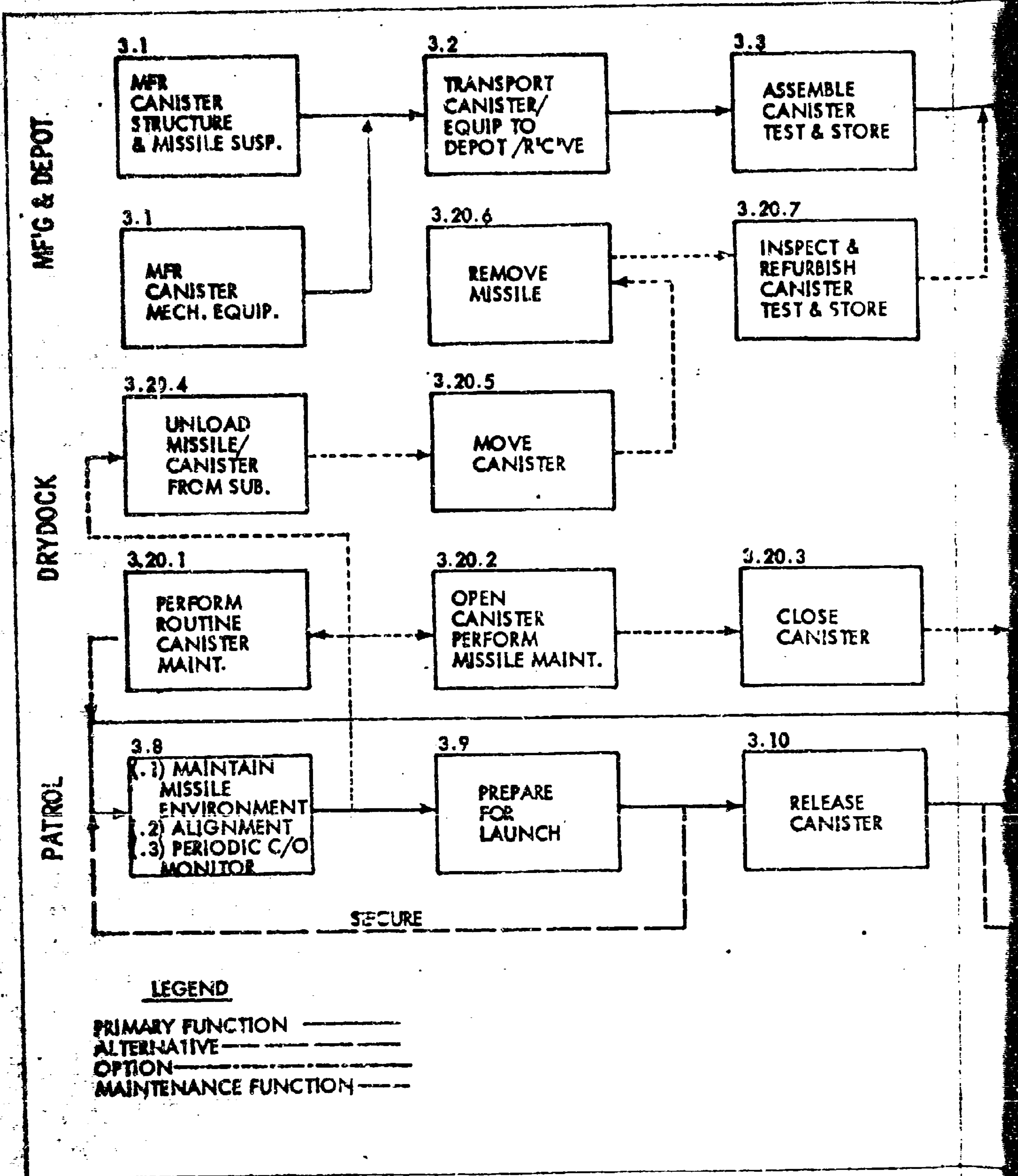
(U) Optional functions which may be required of the Underwater-Launched Missile (ULM) canister include:

h. To provide a hover or dwell capability at predetermined depths after release from the submarine but prior to missile launch.

i. To provide attachment points for recovery of the canister from the surface of the ocean.

3.1.2 OPERATIONAL REQUIREMENTS

(U) The canister shall be capable of performing the functional requirements outlined in paragraph 3.1.1 to the extent required by particular land and sea based operations. Descriptions of the land and sea operations is provided in the following paragraphs. Additionally



MF'G & DEPOT
DRYDOCK
PATROL
3.1
MFR CANISTER STRUCTURE & MISSILE SUSP.
3.2
TRANSPORT CANISTER/ EQUIP TO DEPOT /R'C'VE
3.3
ASSEMBLE CANISTER TEST & STORE
3.1
MFR CANISTER MECH. EQUIP.
3.20.6
REMOVE MISSILE
3.20.7
INSPECT & REFURBISH CANISTER TEST & STORE
3.20.4
UNLOAD MISSILE/ CANISTER FROM SUB.
3.20.5
MOVE CANISTER
3.20.1
PERFORM ROUTINE CANISTER MAINT.
3.20.2
OPEN CANISTER PERFORM MISSILE MAINT.
3.20.3
CLOSE CANISTER
3.8
(.1) MAINTAIN MISSILE ENVIRONMENT
(.2) ALIGNMENT
(.3) PERIODIC C/O MONITOR
3.9
PREPARE FOR LAUNCH
3.10
RELEASE CANISTER
SECURE
LEGEND
PRIMARY FUNCTION
ALTERNATIVE
OPTION
MAINTENANCE FUNCTION

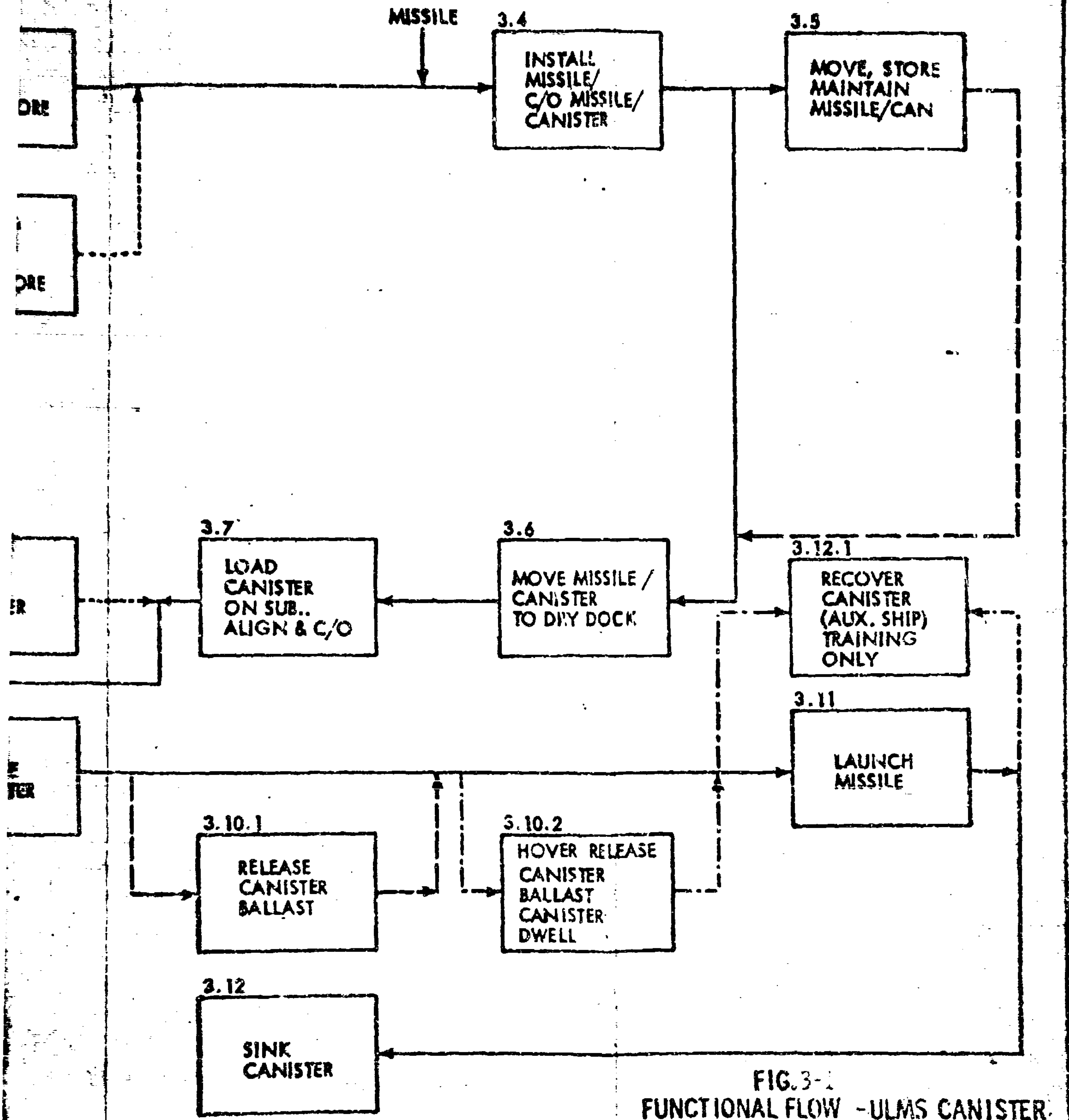


FIG. 3-1
FUNCTIONAL FLOW -ULMS CANISTER

3.1.2 (Continued)

(U) the canister shall satisfy the accepted Reliability, Maintainability, Human Performance and Safety Requirements. The minimum useful life shall be 10 years.

3.1.2.1 LAND OPERATIONS

(U) Land Operations include base operations, short term storage, transport and long term storage performed primarily in the continental United States.

a. The Base Operations Mode includes periods of transporting between storage and maintenance areas, unprotected holding time before and during installation on the ULMS Submarine, and time during maintenance and checkout during this mode.

b. The Short Term Storage Mode relates to temporary storage of a complete canister assembly with or without the missile. The canister shall be operable to the extent required for maintenance and checkout during this mode.

c. The Transport Mode relates to interbase shipment of non-operational complete canister assemblies without the missile installed.

d. The long-Term Storage Mode pertains to controlled storage to the extent of Appendix B. The canister may be stored as components or as a complete assembly, and need not be operable during this mode.

3.1.2.2 SEA OPERATIONS

(U) Sea Operations involving the canister include the suspension of the canister on the submarine, and release of the canister from the submarine while the submarine is on the surface or submerged. Also included are the transit of the canister from point of release to the surface including the optional dwell function and the launch of the missile from the canister. The option for recovery of the canister with or without the encapsulated missile is also included.

a.(U) The Suspension Mode occurs whenever the canister is secured to the submarine whether the submarine is surfaced, submerged or in dry dock. The canister is considered to be completely operable in this mode.

In this mode the exposed skin coefficient of drag (Cdf) shall not exceed 0.0019.

b.(U) Canister Release is required at submarine speeds up to 10 knots. Canister Release is required for one half the missiles from the submarine position on the surface to the submarine keel depth.

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3.1.2.2b. (Continued)

(DL) of 150 feet, and for all the missiles from that depth to 700 feet. Canister Release shall be possible to the following extreme submarine attitudes:

roll, pitch or yaw ± 5° - period 20 sec. or more.

c. (U) The Transit Mode occurs during the period of time from separation of the canister from the submarine to the time the launch sequence is initiated. The canister shall be dynamically stable during transit. The canister/submarine trajectories shall be planned to minimize possibility of collision during transit.

d. (U) During transit, the canister shall be able to Dwell (hover) at a predetermined depth plus or minus 25 feet for established periods of up to 90 minutes.

e. (U) The Launch Phase includes the lid opening, the broaching of the sea surface, the steps required to ignite the missile and release it from the canister and the subsequent actions of the canister and components until they are in equilibrium. The missile launch will be a "hot flyout" launch.

f. (U) To facilitate Canister Recovery, the canister shall "fail safe" to a positive buoyancy state within 120 minutes after release from the submarine. Accommodations for towing and lifting fittings shall be provided.

3.1.3 ENVIRONMENTAL REQUIREMENTS

(U) The canister shall be capable of performing the functional and operational requirements outlined in paragraphs 3.1.1 and 3.1.2 during or after exposure to the environments tabulated in Appendix B.

3.2 DESIGN AND CONSTRUCTION REQUIREMENTS

(U) This section identifies the interfaces assumed valid for this canister design, defines the canister and identifies areas of specifications which will ultimately govern canister design and construction.

3.2.1 INTERFACE REQUIREMENTS

(U) The canister shall interface with other equipment as shown in Figure 3-2.

3.2.1.1 SUBMARINE INTERFACES

(U) The canister shall interface with the ULMS submarine as follows:

a. (U) Canisters shall be interchangeable between submarines. General structural dimensions are shown in Figure 3-3. Arrangements are shown in reference 2, Appendix D. Electrical interfaces are not yet established but are anticipated to be similar to those used on presently deployed SSB(N) submarines. Hydraulic system working pressure will be either 1300 or 3000 psi.

b. (U) The canister shall produce no dynamic coupling with its structural interface at the submarine supports that would affect canister operation or create loading conditions greater in magnitude than those specified in Appendix B.

3.2.1.2 MISSILE INTERFACES

(U) The canister shall interface with the ULMS missile as follows:

a. (U) ULMS canisters and missiles shall be interchangeable. General missile dimensions are shown in Figure 3-4.

b. (U) Limit Load Factors to be sustained by the missile are shown in Table 3-1.

c. (U) The missile uses solid propellants.

d. (U) Interface requirements not considered essential to this study have not been specifically established.

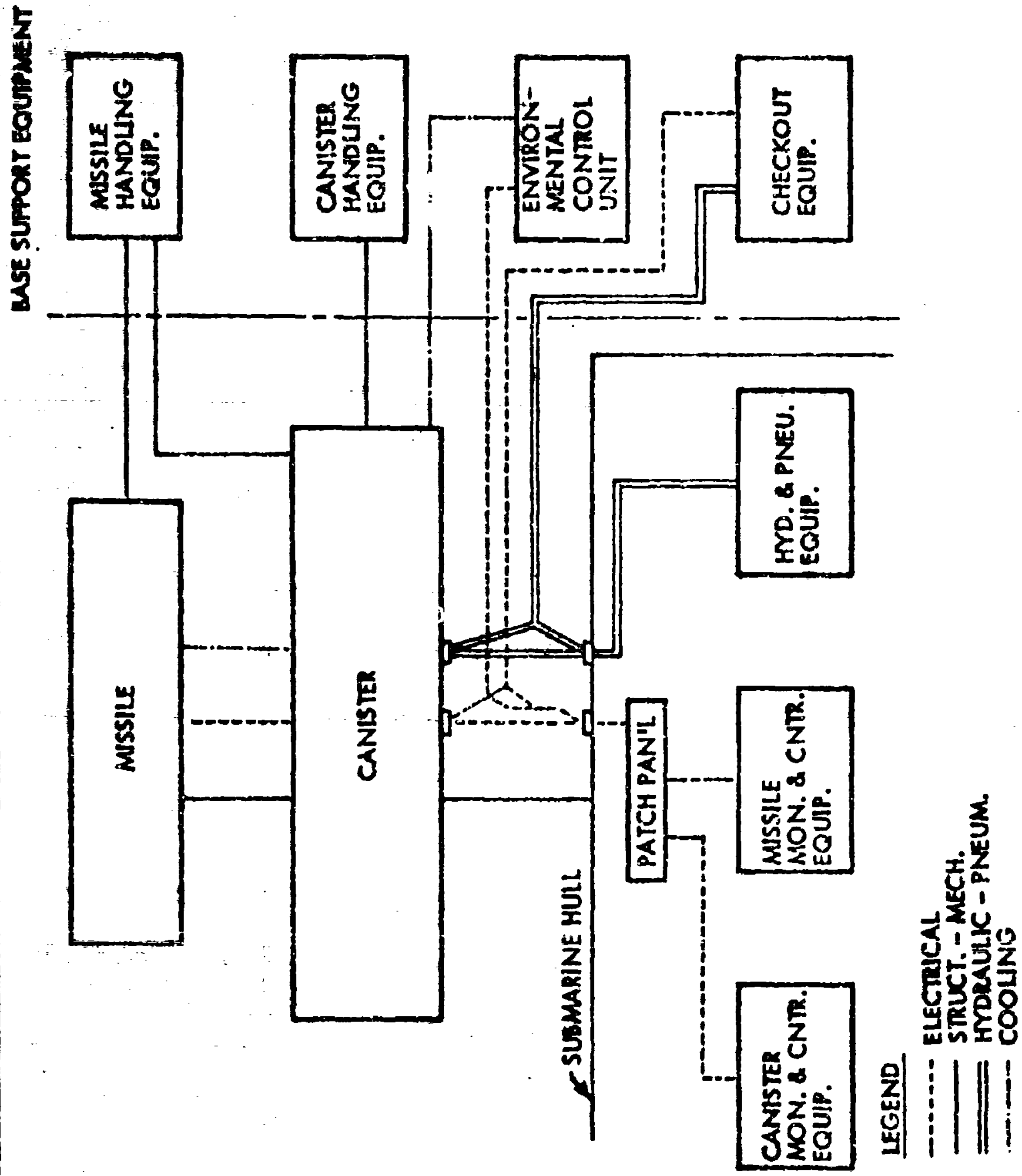

Fig. 3-2
INTERFACE SCHEMATIC

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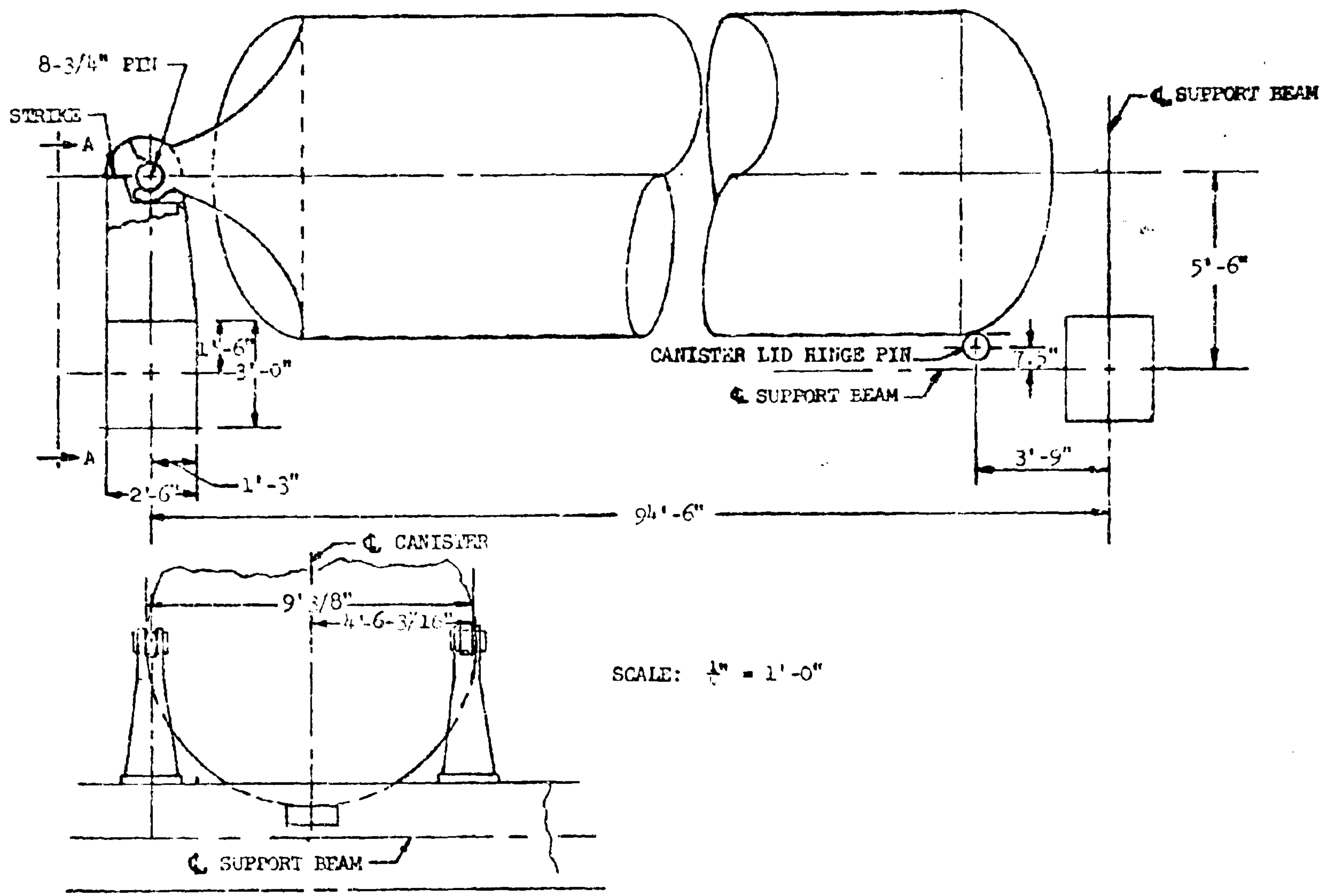

SCALE: 1/4" = 1'-0"

Figure 3-3 SUBMARINE CANISTER SUPPORT INTERFACES

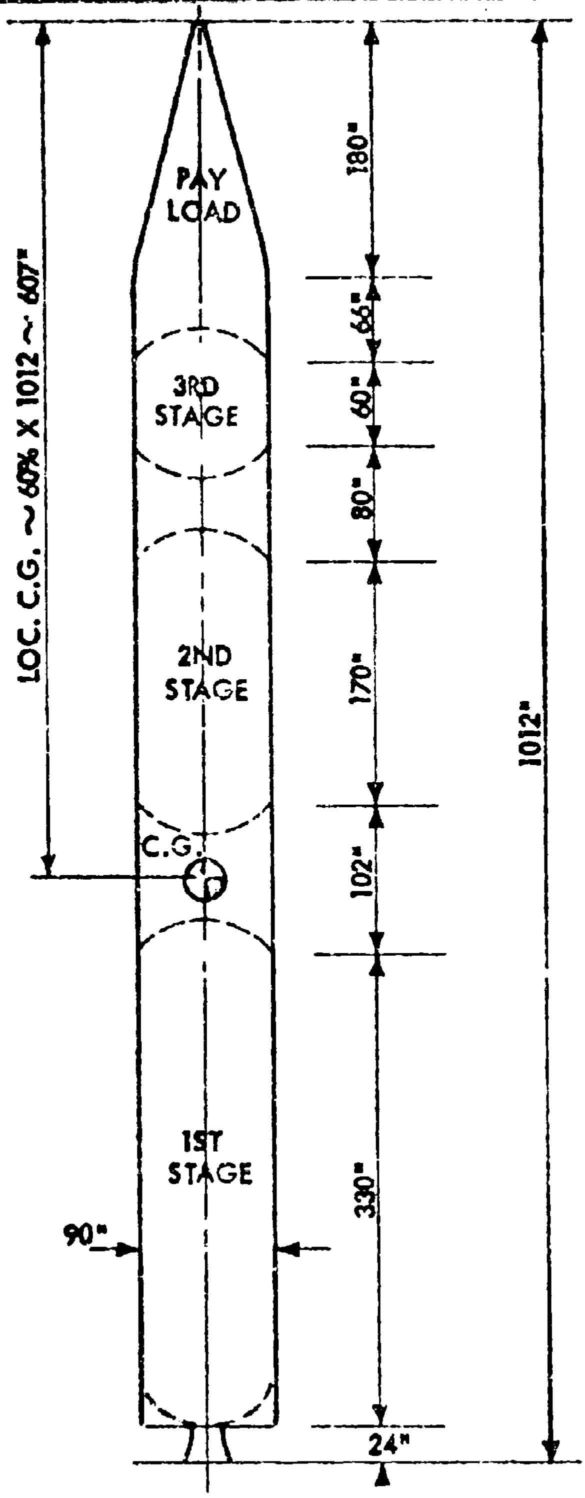

Figure 3-4 MISSILE PROPORTIONS

3.2.1.2 (Continued)

Table 3-1

MISSILE TRANSPORTATION-SUSPENSION LIMIT LOAD FACTORS

Condition	Description	Location	Design Limit Load Factor
1	Longitudinal Axis	Missile Skirt	± 6.0 g's
2	Lateral	Supported Skin i.e. Motor Case Heads	± 3.0 g's or 300 psia
3	Lateral-Longitudinal	Unsupported Skin or Rocket Case	30 psia
5	Longitudinal	Supported Skin	300 psia

3.2.1.3 BASE SUPPORT EQUIPMENT INTERFACES

(U) The base support equipment has not been specifically identified. Missile and Canister Handling Equipment is assumed as are the Environmental Control Unit and Checkout Equipment.

3.2.2 CANISTER DEFINITION

(U) The interrelation between the submarine, canister and missile requires that baseline configurations be assumed prior to final design. Iterative modifications to each are made until the system design has been accomplished. For purposes of this document the following assumptions are valid:

3.2.2.1 MAJOR CANISTER COMPONENTS

(U) The major components of the ULMS canister include the Structural Shell, Access Hatches and Lids, and the Missile Suspension System.

3.2.2.2 CANISTER SUBSYSTEMS

(U) The subsystems of the ULMS canister include:

a. The Electrical System

b. The Environmental Control System

c. The Hydraulic System

d. The Ballast System

e. The Pneumatic System (optional)

f. The Corrosion Resistance System

3.2.3 SPECIFICATIONS AND STANDARDS

(U) The following specifications and standards for design and construction of the ULMS canister have not been specifically identified but were considered to the extent to which they applied to this study.

a. Reliability

b. Maintainability

c. Human Performance

d. Safety

e. Materials, Parts and Processes

f. Standard and Commercial Parts

g. Interchangeability and Replaceability

h. Electromagnetic Interference

i. Corrosion of Metal Parts

j. Moisture, Fungus and Marine Growth Resistance

k. Workmanship

l. Identification and Marking

m. Storage

n. Government Furnished Property List

o. Engineering Critical Component List

p. Logistic Critical Component List

4 DESIGN

(U) Configuration studies based on the requirements of the Underwater-Launched Missile System (ULMS) described in Reference 1 led to the submarine-missile-canister conceptual design proposed by Reference 2. (See Figures 1-1 and 4-1) Feasibility of the canister proposed (Figures 4-2 and 4-3) was verified by studies and calculations of the general configuration, the structural components, the lid mechanism and the lateral suspension system. Cursory analysis of the required subsystems provided assurance that a canister could be built to satisfy the system requirements. This section summarizes the studies and calculations performed in preparation of the canister design and expands on the subsystem designs.

4.1 GENERAL CONFIGURATION

(U) The external configuration of the canister was conceived during submarine-missile packaging studies previously noted. A trunnion and latch support the canister in a partial fairing outside the submarine pressure hull and permit canister release on signal by utilizing canister buoyancy and other hydrodynamic forces (Figures 4-4 and 4-5). Two canister configurations are required; a top and bottom released canister.

(U) The specific canister size shown herein (9 ft. O.D. by 92.5 ft. long) was selected after consideration of submarine packaging constraints and missile configurations which satisfy ULMS range-payload requirements.

(U) The partially exposed stowage mode on the submarine dictated a smooth exterior skin on the canister to minimize drag. Because of this constraint, an internally ring-stiffened cylinder was selected.

(U) Effects of the weapon threat postulated in Reference 1 and the resistance to shock of existing missiles outlined the requirements of lateral and longitudinal missile suspension inside the canister (Figure 4-6). Air bags at missile strong points were selected for the lateral suspension system. Longitudinal suspension will be provided by combinations of cables or Belleville Spring sets and possibly a launch tube liner. Tentatively, a Belleville Spring System is proposed.

(U) Dogged lids seal the ends of the canister during operations and are opened at launch to allow missile flyout (Figures 4-7 and 4-8).

(U) Electrical power and electronic signals are transmitted by umbilicals between the submarine, canister and missile subsystems and components such as the environmental control system, position sensors, guidance and control and squib units.

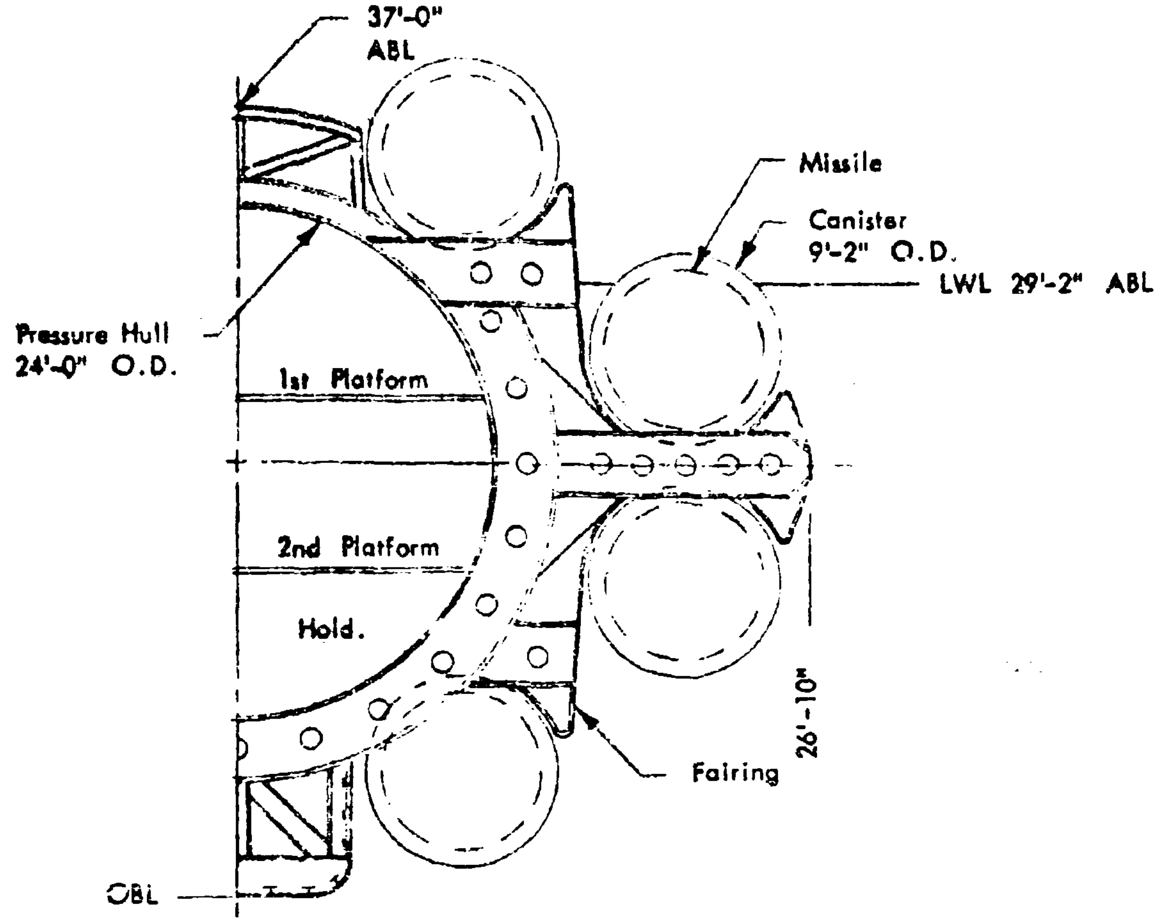

Fig. 4-1 TYPICAL CROSS-SECTION

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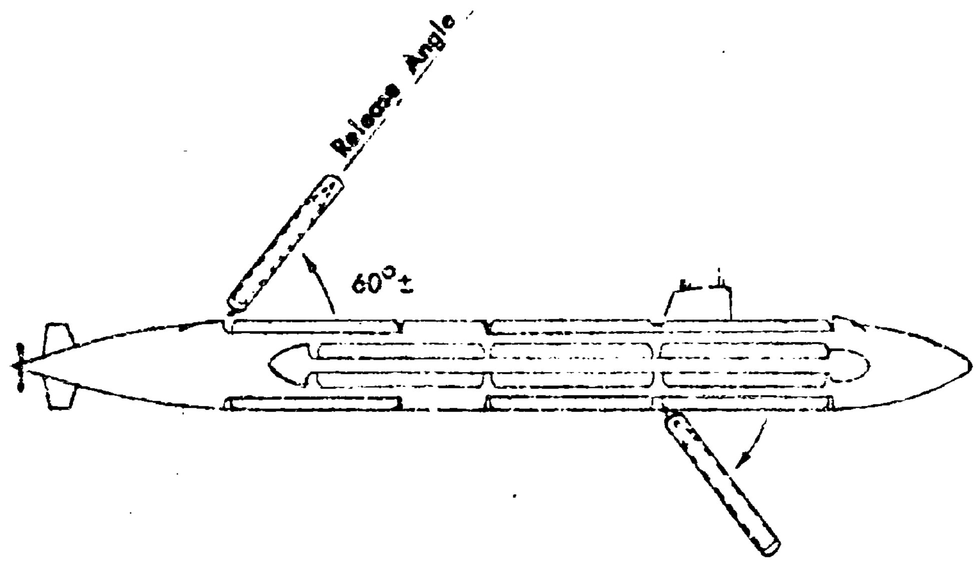

Fig. 4-2 PYLON SUBMARINE - CANISTER DEPLOYMENT

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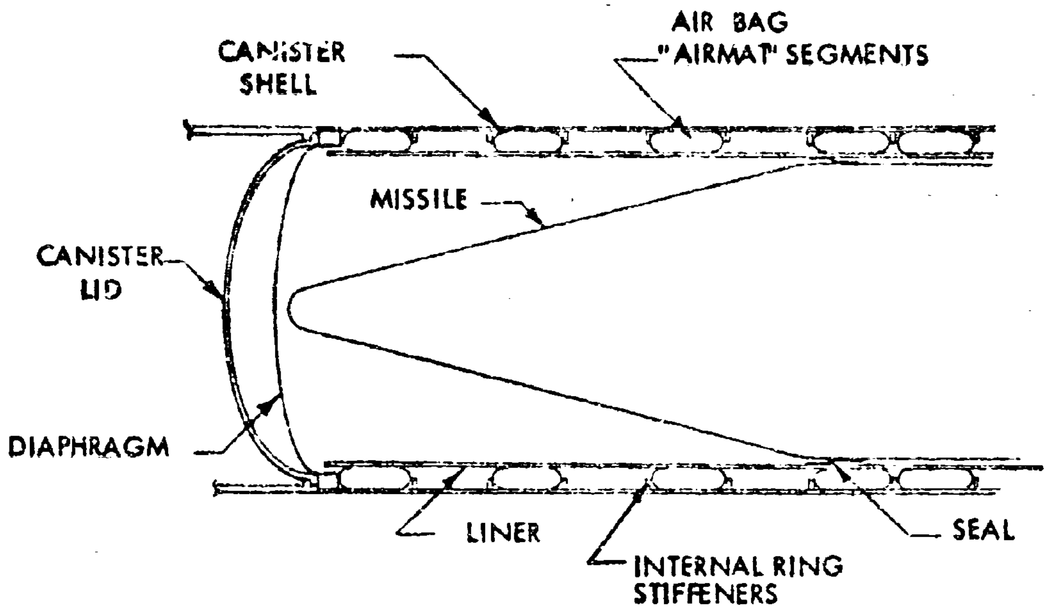

Fig. 4-3 CANISTER

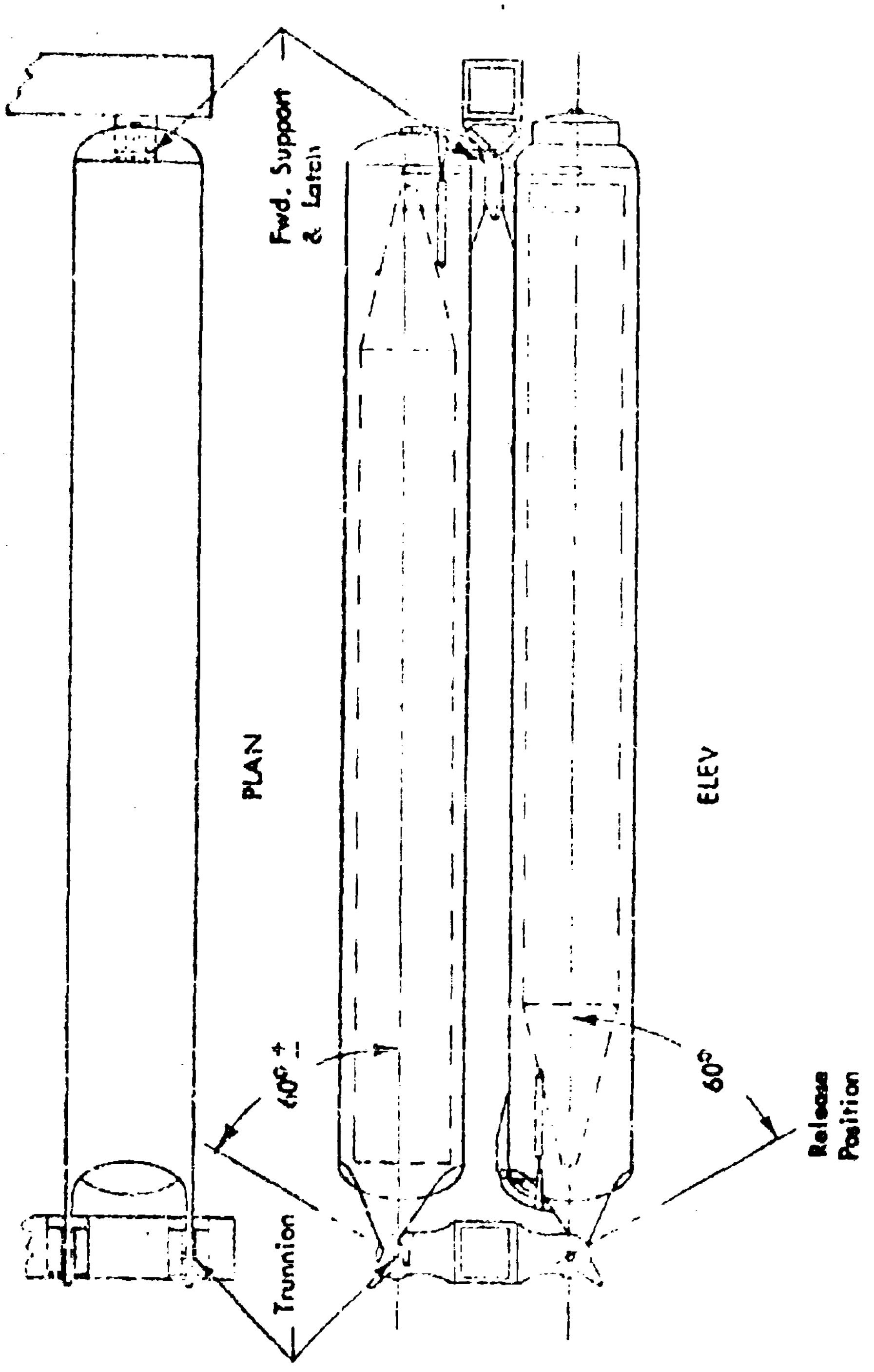

Fig. 4-4 3 POINT CANISTER SUSPENSION

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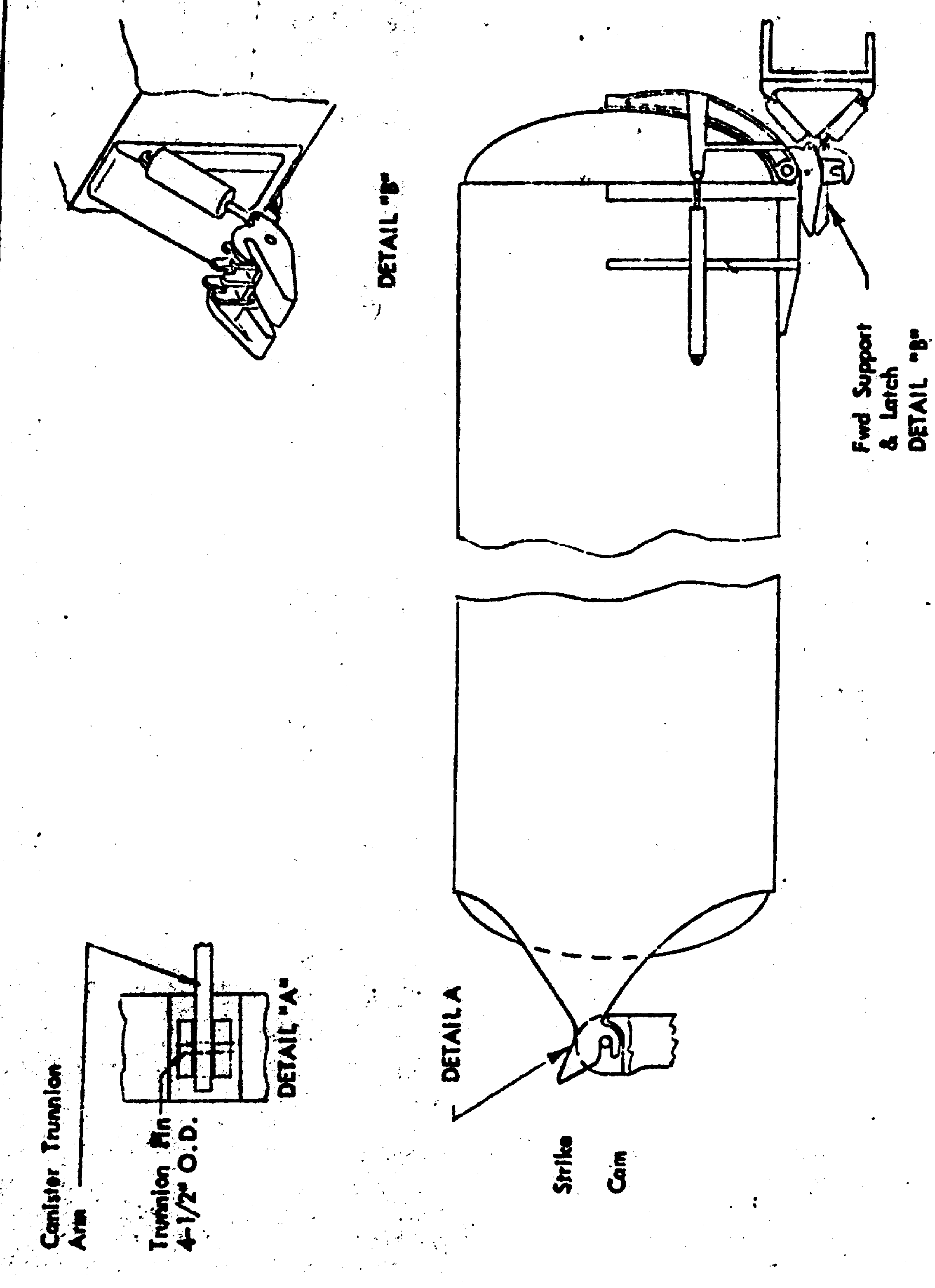


Fig. 4-5 CANISTER SUSPENSION & LATCH

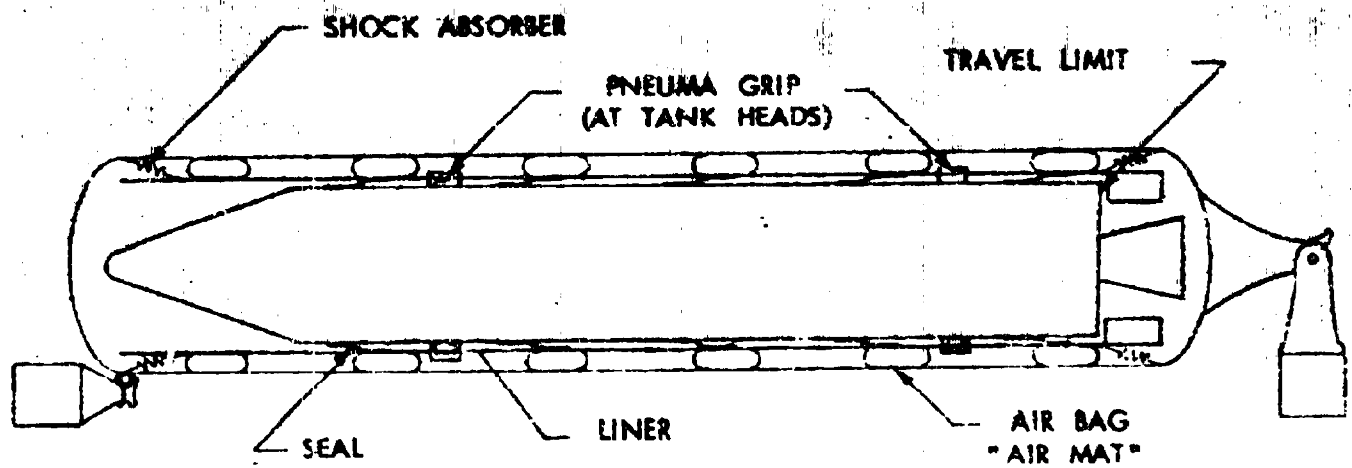


Fig. 4-6 MISSILE SUSPENSION SYSTEM

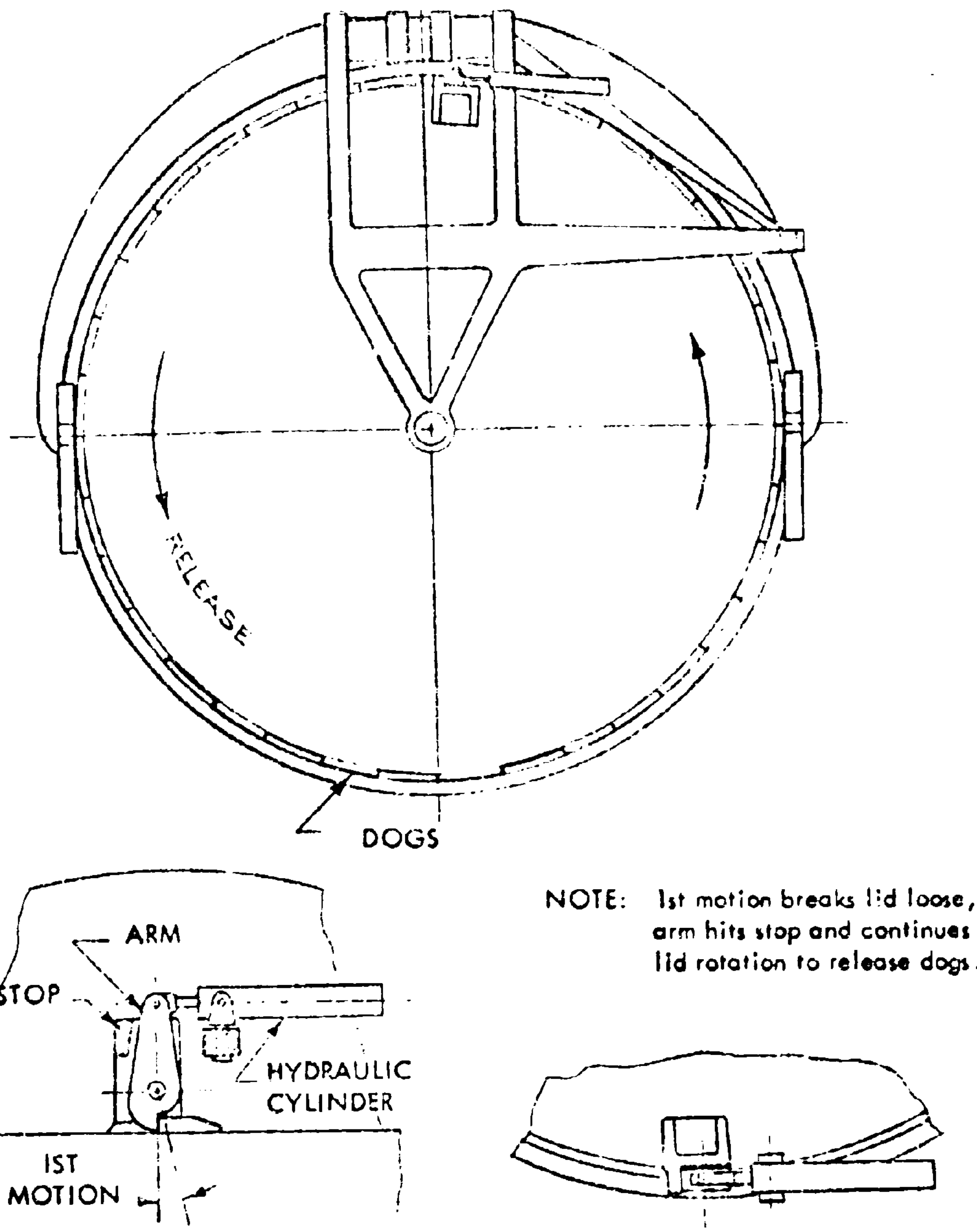
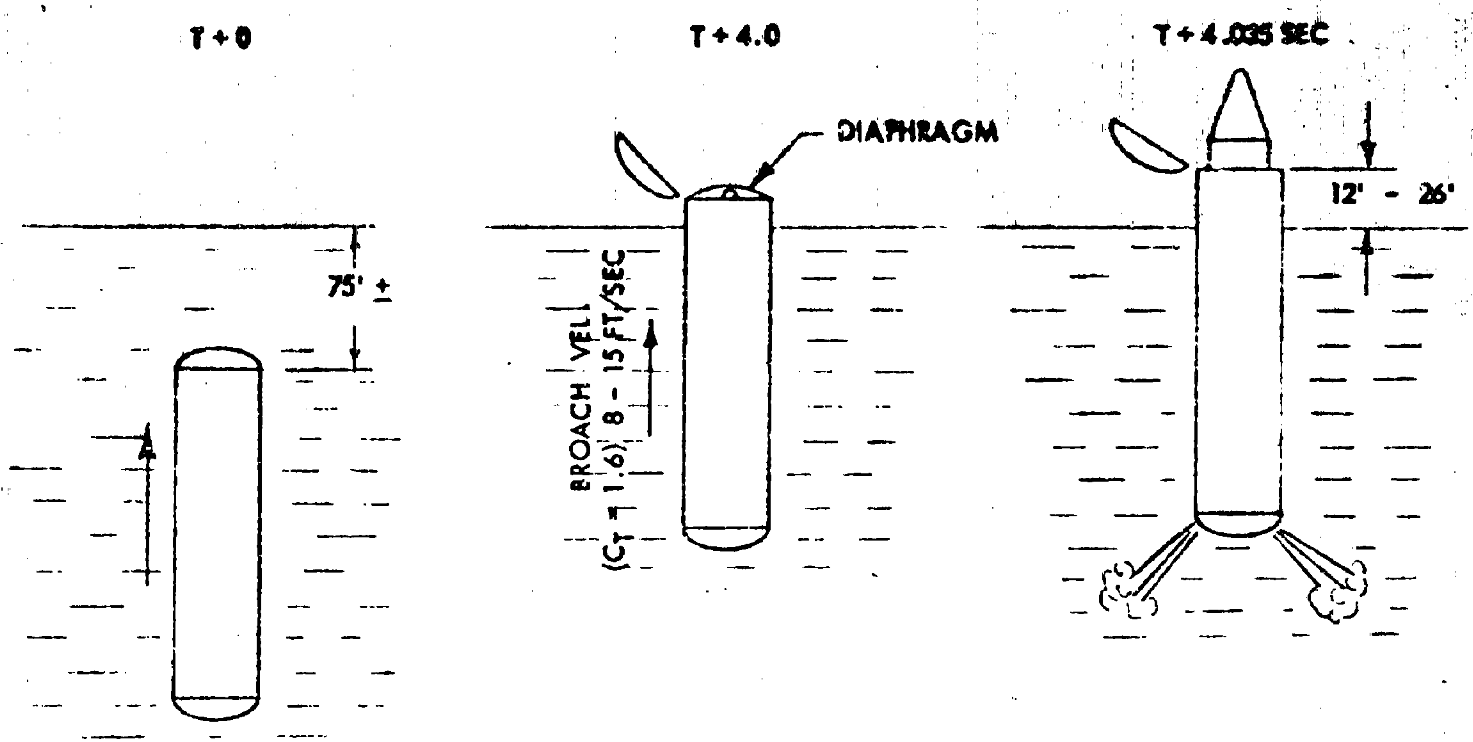


Fig. 4-7 CANISTER LID ROTATING MECHANISM



TOP & BOTTOM LIDS UNLATCHED (DEPTH SENSOR)

TOP LID OPENED (DEPTH SENSOR)

STAGE 1 IGNITED (LID OPEN SIGNAL)

FULL THRUST DEVELOPED

BOTTOM LID BLOWN CLEAR (ENGINE EXHAUST PRESSURE)

TOP DIAPHRAGM BROKEN (MISSILE MOTION)

Fig. 4-8 CANISTER/MISSILE LAUNCH SEQUENCE

4.1 (Continued)

(U) Internal ballast adjusts the percent of positive buoyancy and positions the center-of-gravity for stable transit to the surface. External ballast on bottom canisters provides temporary negative buoyancy to drop those canisters below the submarine until their paths can clear Figure 4-9). At an appropriate time the external ballast is released from the bottom released canister and the canister transits to the surface similar to a top release canister.

4.2 WEIGHT AND BUOYANCY

(U) The estimated weight based upon the stated assumptions is as follows:

	Wt. in Pounds	
Cylinder		
Skin - 108 inches O.D. - 0.75 inch thick 85.84 ft. long (109.5 in. O.D. with liner - wt. 75,400 lbs)	74,200	
Rings - 4 inch deep x 0.75 inch thick at 30 in. spacing	7,350	
End Rings - 6 inch deep x 2 inch thick - 2 ends	2,300	
		83,850 lbs.
Lids		
Skin - 61 ft^2 x 0.75 inch thick x 2 ends	3,730	
Stiffeners - 10.5 ft. x 4 inch x 0.75 inch x 8/end x 2 ends	1,720	
Ring - 26.2 ft. circumference x 6 inch x 0.75 x 2 ends	800	
Actuators & Arms (estimated)	950	
		7,200 lbs
Lateral Suspension (estimated)		5,500 lbs
Longitudinal Suspension (Belleville Springs)		
Ring	1,150	
Spring Units 36 x 210 lbs/unit	7,500	
		8,650 lbs
Miscellaneous (estimated)		5,000 lbs
SUB-TOTAL . . . . for 92.5 ft length 1194 lbs/ft.		110,200 lbs
Optional Liner 85 ft. x 92 inch O.D. x 0.1875 inch thick plus additional weight of skin at 109.5 in O.D.		19,800
TOTAL . . . . 1410 lbs/ft.		130,000 lbs

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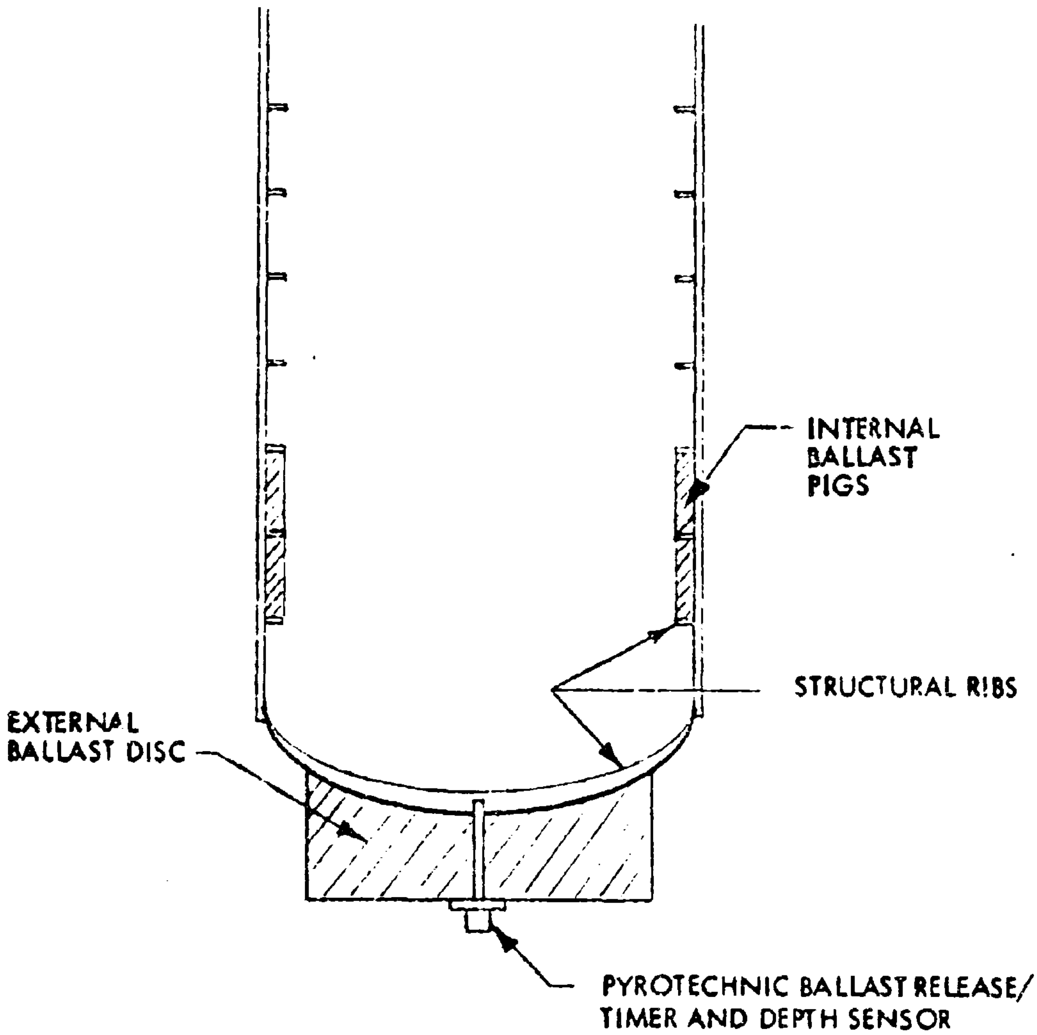

Fig. 4-9 BALLAST SUSPENSION

4.2 (Continued)

(U) The buoyancy is the difference between the total canister weight and the weight of the displaced sea water summarized below.

		Displacement (∇) Ft^3	(with liner)
Cylinder - 85.84 feet long 9.04 ft. dia. (with liner 9.12 ft. dia.)		5,500	(5,600)
Lids - 2 each, 2.33 ft. x 8.5 ft. half ellipse		125	
Miscellaneous Structure and Attachments (estimated)		25	
		5,650 ft^3	(5750 ft^3)
(with liner ~			
Weight displaced Sea Water 5,650 ft^3 x 64 lbs/ft^3		361,500 lbs	(368,000 lbs)
Weight of Canister	110,000 (130,000)		
Weight of Missile	225,000		
		325,000 lbs	(355,000 lbs)
Buoyancy lbs.		36,500	(13,000)
% Buoyancy		10.1	(3.53)
Wt at 6% Buoyancy - lbs.		341,500	(347,000)
Lbs. Ballast required for 6% Buoyancy		16,500	(8,000)

The assumed liner design looks marginal. Positive buoyancy should fall between 4 and 7 percent. A larger diameter may be required if the liner suspension system is used.

4.3 TRANSIT TRAJECTORY

(U) Preliminary calculations were made to determine the approximate transit trajectories of the canister. Based on the estimated Canister with Missile Characteristics noted in Table 4.3-1 preliminary canister trajectory characteristics were established. See figures 4-10, 4-11, 4-12, 4-13, 4-14, and 4-15.

TABLE 4.3-1

Canister

Length (excluding trunnion arms)	89.5 Feet
Diameter	9.2 Feet
Center of Gravity from Aft Perpendicular	
Positive Buoyant	36.8 Feet
Negative Buoyant	34.6 Feet
Center of Buoyancy from Aft Perpendicular	44.8 Feet

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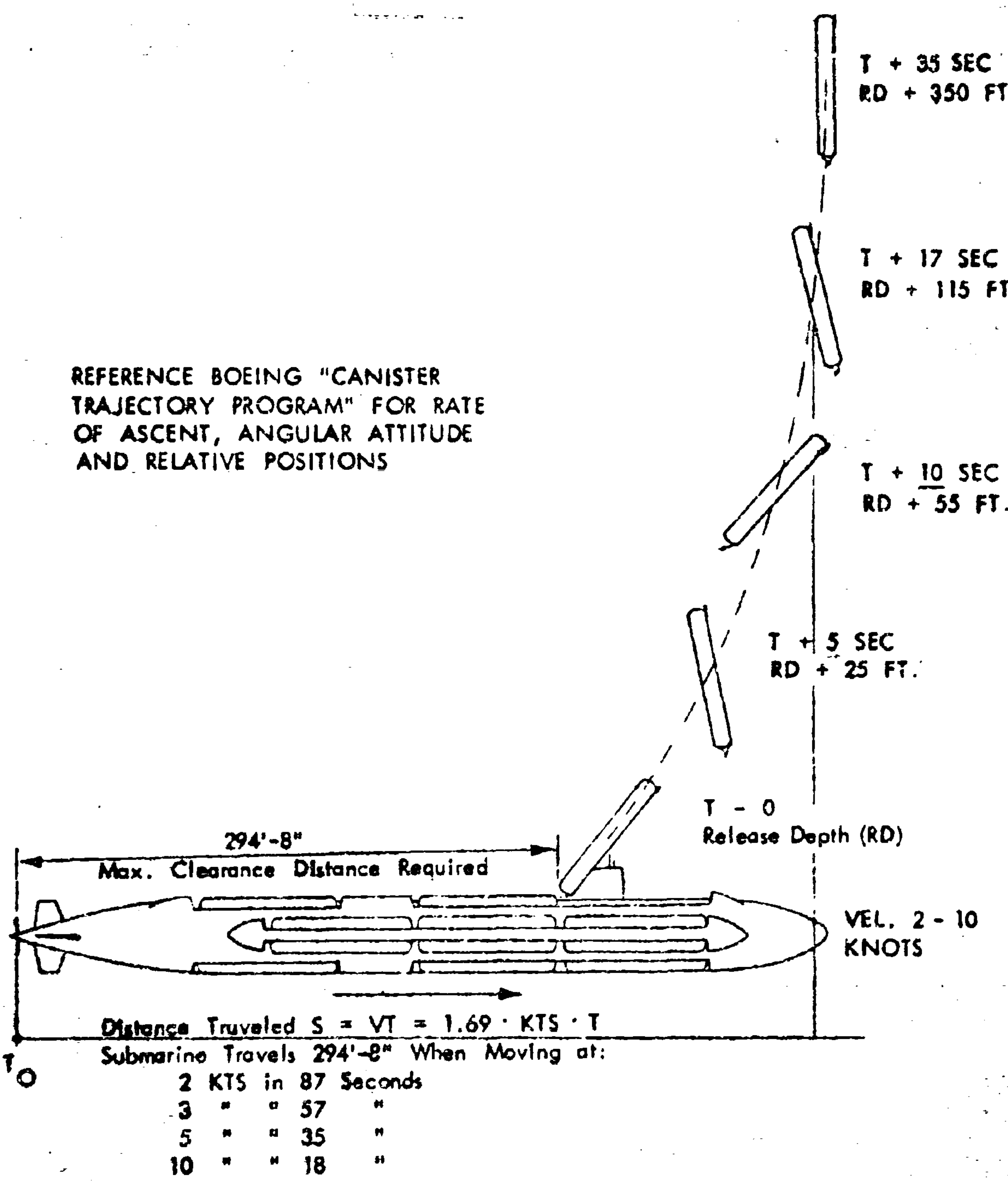

Fig. 4-10 TOP RELEASE CANISTER TRAJECTORY

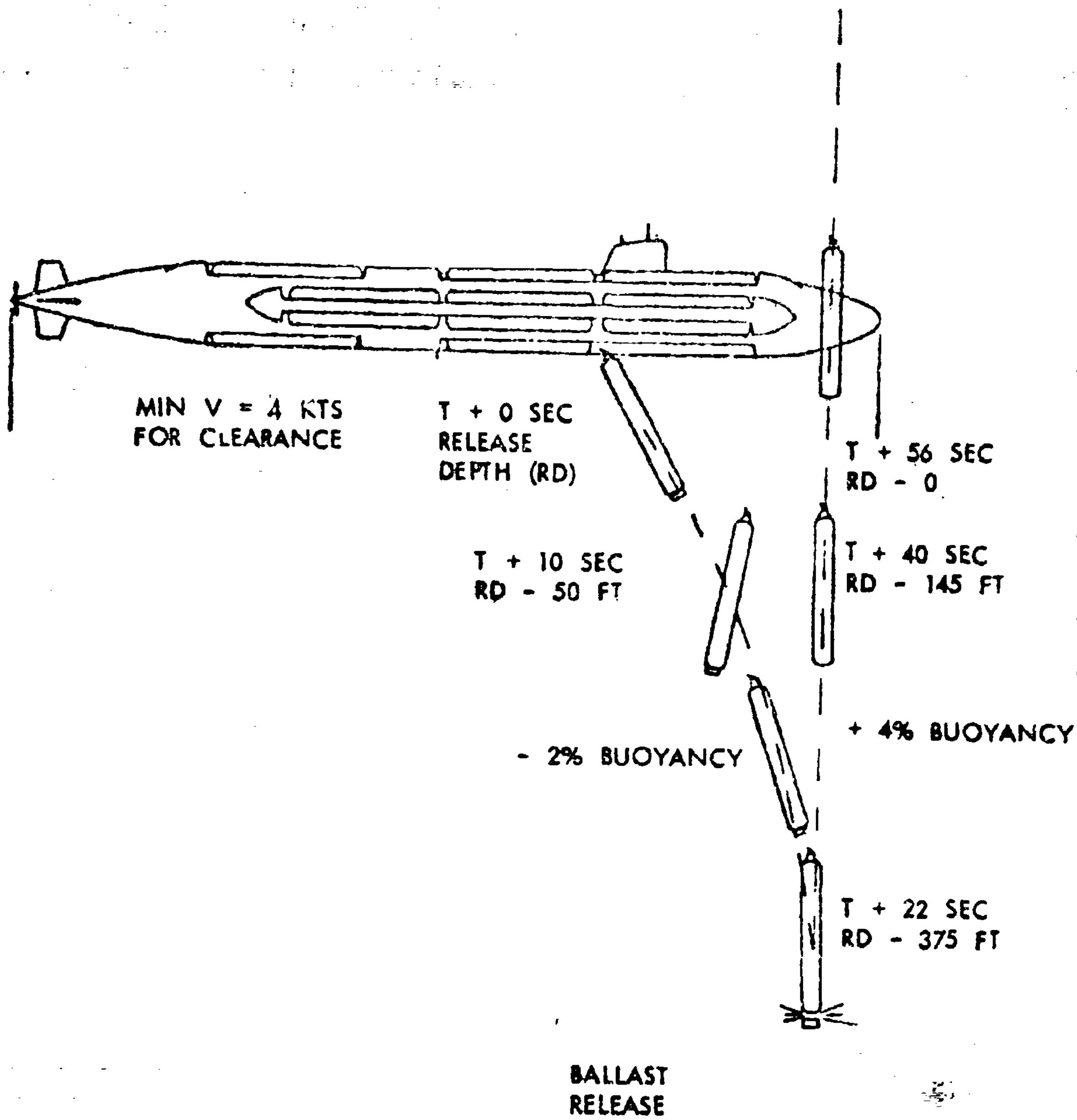

Fig. 4-11 BOTTOM RELEASE CANISTER TRAJECTORY (Example)

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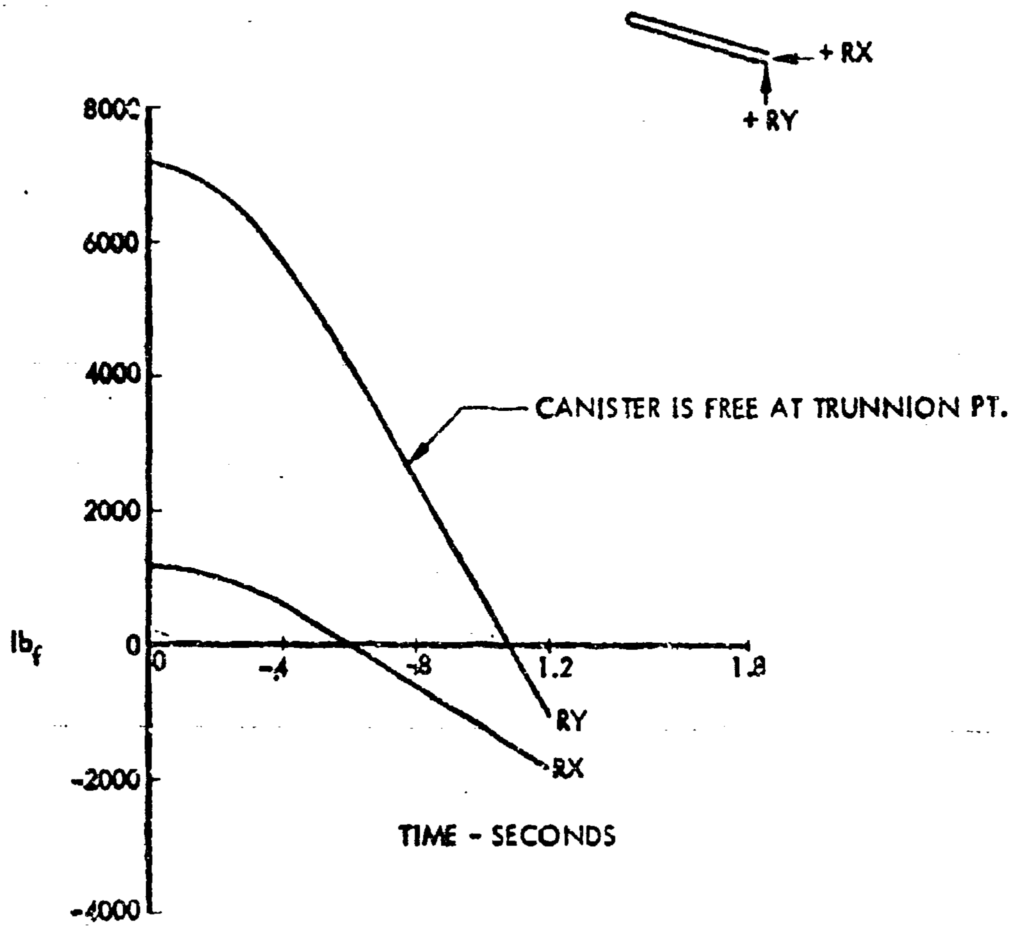

Fig. 4-12 TRUNNION REACTION FORCES VS TIME FROM RELEASE

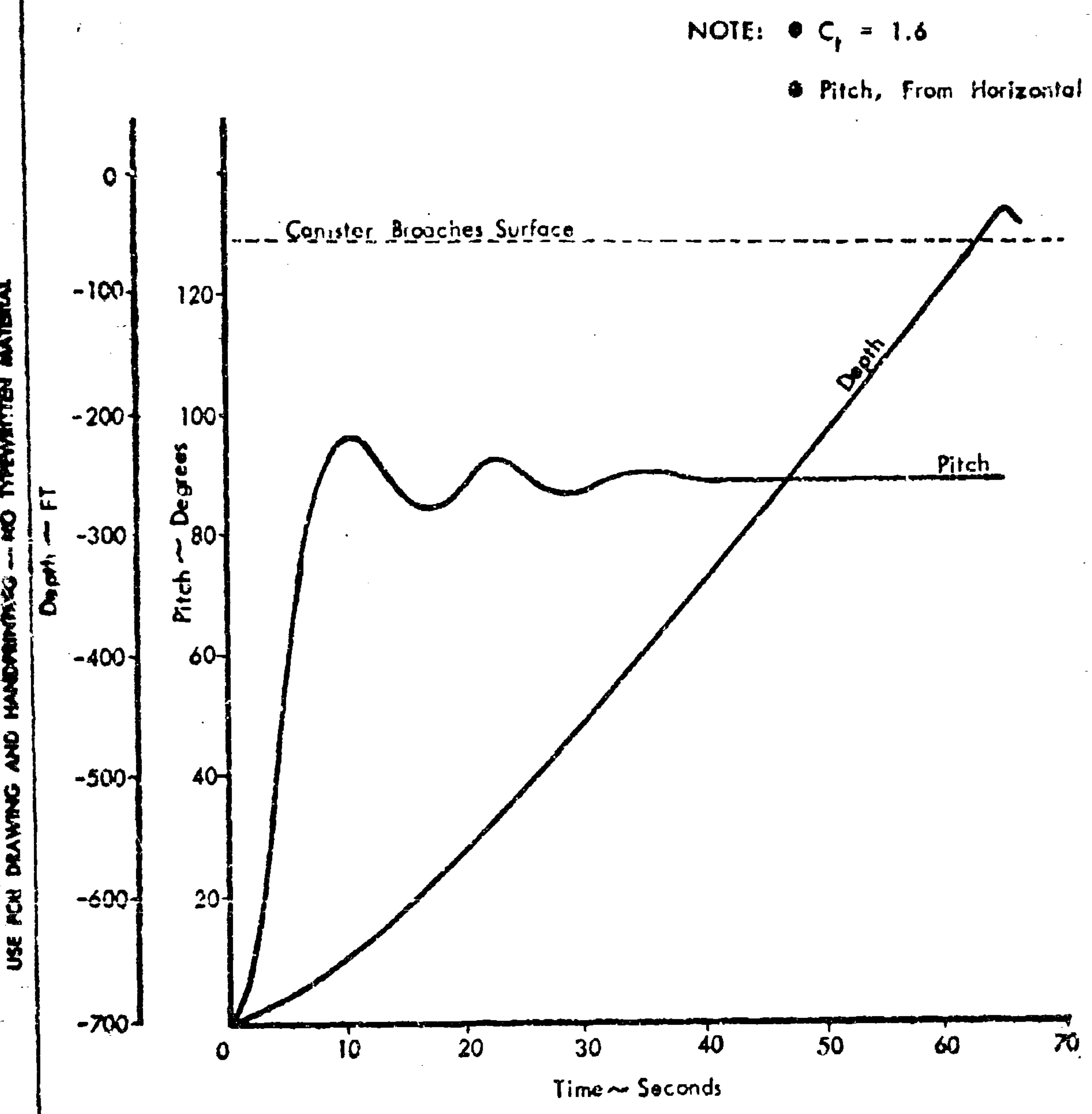

Fig. 4-13 CANISTER TRAJECTORY

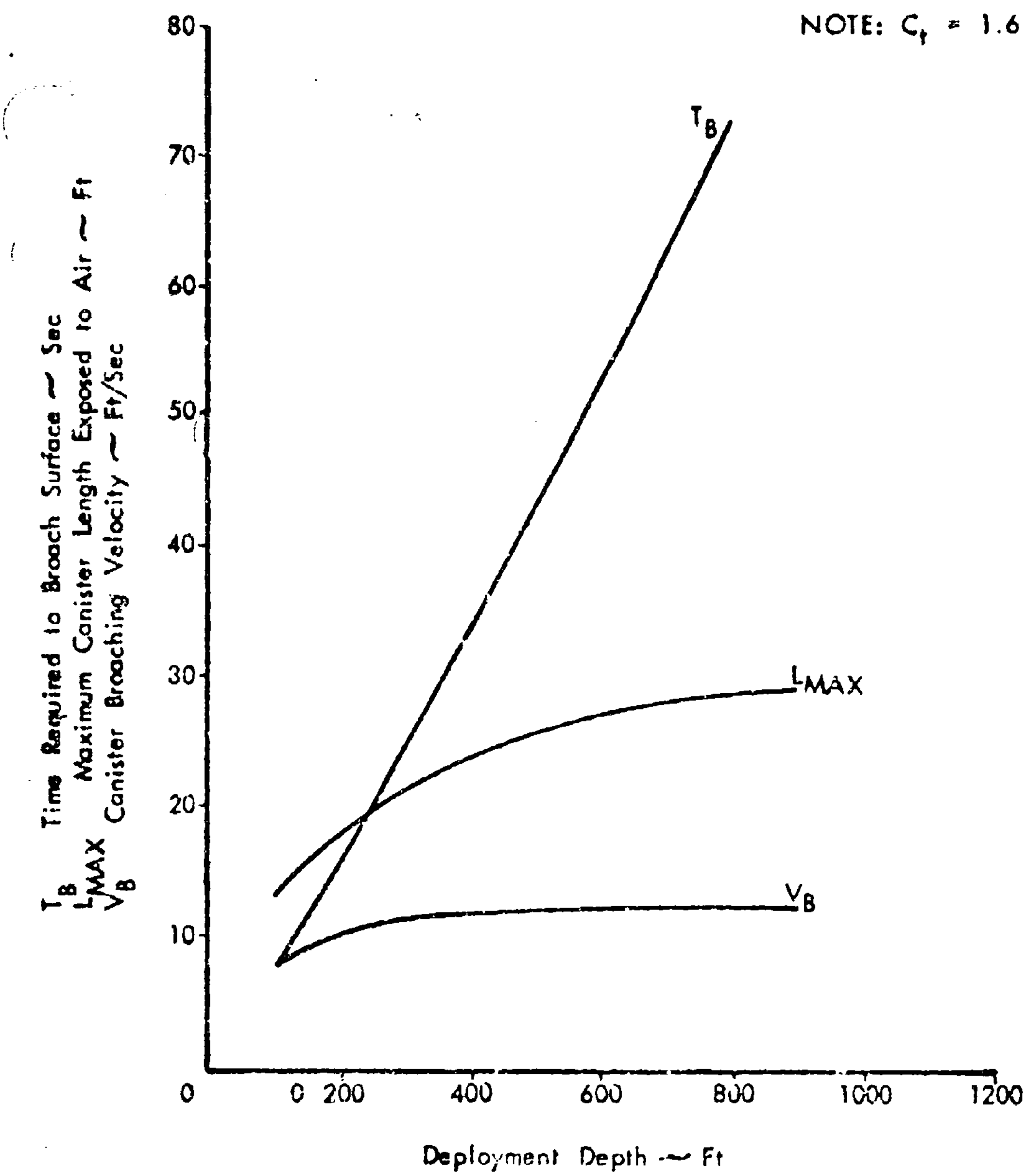

Fig. 4-14 COMPARISON OF DEPLOYMENT DEPTH

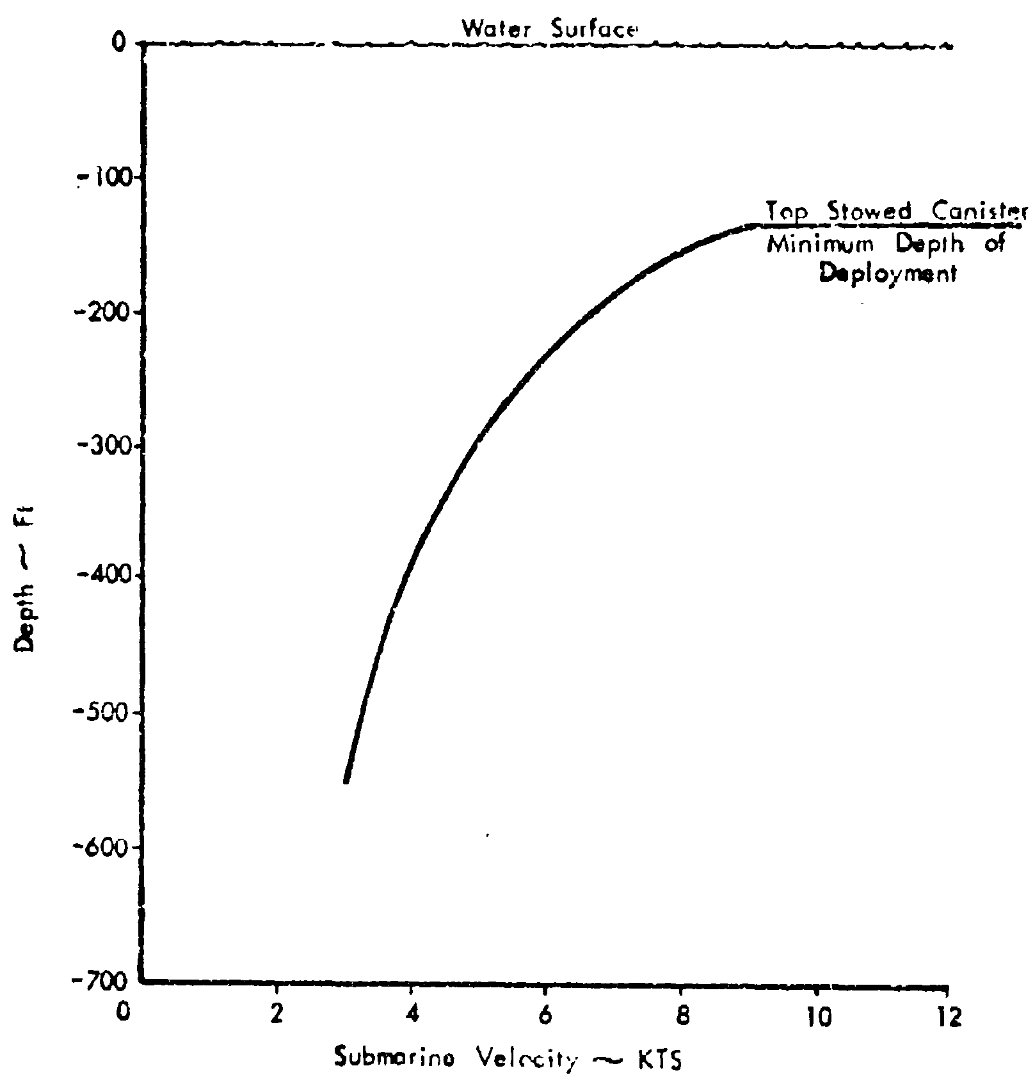

Fig. 4-15 MINIMUM SUB-VELOCITY - TOP CANISTER

4.3 (Cont'd)

(U) Weight	
Positive Buoyant	157.8 Tons (Long)
Negative Buoyant	169.0 Tons (Long)
Volume	5,748.0 Cubic Feet
Percent Buoyancy	
Positive	4%
Negative	3%
Total Drag Coefficient (C_t)	1.6 (With Trajectory Rings)
Normal Force Coefficient (C_N)	0.342
Wetted Surface Area (S_W)	2,586.0 Square Feet

TABLE 4.3-1

Canister Characteristics (with Missile)

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4.4 STRUCTURAL DESIGN

(U) This section describes the approach and methods used in arriving at the structural design of the ULMS canister defined in ref. 2 and this document. Also discussed are the designs of mechanical components which are critical to the structural integrity of the canister.

(U) The material used in this structural design is HY80 steel with properties as tabulated below. Other materials such as HY150 and Glass Filament materials were investigated but, due to their relatively unproven status and lack of outstanding characteristics for this application, were bypassed in favor of HY80.

	Yield Strength psi	Ultimate Strength psi	Elongation %	Modulus of Elasticity $x\ 10^6$	Density lb. per in^3
HY80	80,000	100,000	14	29 - 30	0.28

The designer has considered 48,000 psi as the allowable stress in tension, compression and bending and 22,000 psi as the allowable shear stress.

4.4.1 CYLINDRICAL SHELL

(U) The cylindrical shell due to the requirement for a streamlined exterior surface in this submarine-canister configuration (reference 2) is an interior ring stiffened cylinder. Section 3.1 and Appendix B describe the performance and environmental requirements. The canister has been treated as a uniformly loaded simple beam with pinned ends. The combined loading conditions of bending, pressure at operating depth and specified weapon effects are considered when applicable. Of these, two combined load conditions appear critical to the structural design of the canister.

a. The bending of canisters when horizontally supported by the ends only and subjected to a 3 "g" impact from the internally supported missile. This may occur during handling or to top canisters when the submarine is surfaced and is accelerated by a near miss explosion to the peak particle velocity of the water.

b. The bending, shell buckling, yield and general instability of the canister when subjected to the 3 "g" impact and sea water pressure at operating depths.

4.4.1.1 DEFLECTION

(U) In bending, the canister cannot deflect more than the missile. By estimating the worst case deflection of the missile and matching the maximum canister deflection to that deflection, one check on the canister stress in bending can be calculated.

4.4.1.1 (Continued)

(U) Assuming the missile parameters as follows;

Missile weight - 225,000 lbs

Missile length - 1012 (support length ~ 832 inches)

Missile diameter - 90 inches

Maximum deflection $= \frac{5}{384} \frac{WL^3}{EI}$ Uniform load-pinned ends

Maximum Moment $M = \frac{WL}{8}$

Fibre stress $fs = \frac{MY}{I}$

$$M = \frac{fsI}{Y}$$

$$\frac{fsI}{Y} = \frac{WL}{8}$$

$$8fsI = WLY$$

$$W = \frac{8fsI}{LY}$$

$$= \frac{5}{384} \times \frac{8fsIL^3}{LYEI} = \frac{40}{384} \frac{fsL^2}{YE} = 0.1041 \frac{fsL^2}{YE} \qquad (1)$$

where fs = fibre stress

L = length

Y = distance from neutral axis to outermost fibre

E = Youngs Modulus of Elasticity

<u>For the missile</u>

Assume fs = 10,000 psi

L = 832

Y = 45

E = 10,000,000

4.4.1.1 (Continued)

(U) from (1)

Missile $= 0.1041 \dfrac{10,000 \times (832)^2}{45 \times 10,000,000} = \underline{\underline{1.6}}$ inches Maximum Missile Deflection

<u>For the canister</u>

$= \dfrac{5}{384} \times \dfrac{WL^3}{EI}$

W(est) $= 350,000$ lbs $= 3.5 \times 10^5$

L(length) $=$ 90.75 ft. $=$ 1088 inches (Figure 3.3)

D(diameter) $=$ 108 inches

E $=$ 30,000,000 psi

(defl.) $=$ 1.6 inches (maximum allowable)

384 EI $= \dfrac{5WL^3}{384}$ E

$= \dfrac{5(3.5)\ 10^5\ (1,088)^3}{384\ (1.6)\ 30\ (10^6)}$

I(required) $= \dfrac{22.45\ (10^5)}{18.4} = 122,000\ in^4$

I(required for 3g's) $= \qquad = 366,000\ in^4$

$I = r^3 t$

$t = \dfrac{I}{r^3}$

$r = 54$ inches $I = 366,000\ In^4$

$t = \dfrac{36.6\ (10^4)}{(54)^3} = 0.743$ in. minimum canister thickness from allowable deflection

from $M = \dfrac{WL}{8} = \dfrac{3(3.5)\ 10^5\ 1088}{8} = 14.3\ (10^7)$

Bending Stress with t = 0.743 $fb = \dfrac{MY}{I} = \dfrac{14.3(10^7)54}{36.6\ \ 10^4} = 21,100$ psi.

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4.4.1.2 SHELL BUCKLING, YIELD AND GENERAL INSTABILITY

(U) Three primary modes of failure, Shell Buckling, Shell Yield and General Instability generally govern this type of structural design (reference 3, Chapter IV, Section 8). Considering these failure modes the Boeing Optimization Program for Submersibles (BOPS) (reference 4) was used to determine a minimum weight design. Based on inputs listed below the resulting structure defined was a 0.375 inch thick HY 80 steel skin supported by 4 inch structural tees on 11 inch centers with 3 king frames equally spaced in the length of the canister.

(DL) The inputs to the (BOPS) program included the following:

a.	Factor of Safety	1.5 (for shell yield) 2.0 (for stability)
b.	Operating depth	700 feet
c.	Ring Spacing	8 - 36 inches
d.	Ring geometry	T - Section
e.	Material Properties	of HY-80 Steel
f.	Shell Diameter	8 - 10 feet

(DL) Subsequent to the BOPS program design additional factors appeared, which affect the design constraints; A modified operating depth due to the trajectory of bottom release canisters increased the operating depth to about 1050 feet. The ring spacing and geometry used in the minimum weight design appeared to be too restrictive on the lateral suspension system.

(U) A heavier skin (0.50 inches thick) with rectangular shaped rings at 24 to 30 inches on centers was arbitrarily selected. King frames were arbitrarily deleted. This configuration was presented as the original concept in reference 2.

(DL) Following are calculations to check the adequacy of that design.

Applying derivations of Windenberg's expression for shell buckling in which:

$$pc = \frac{2.60\, E(t/D)^{5/2}}{L/D - 0.45\, (t/D)^{1/2}} \quad \text{(from reference 3, Ch. IV, Section 8.4)} \quad (1),$$

an assumed thickness may be readily checked against the frame spacing, the canister diameter and the collapse pressure.

where

pc = collapse pressure, psi.
operating depth 1050 ft. X safety factor 1.5 X 0.4444 psi/ft.

= 700 psi (required minimum)

4.4.1.2 (Continued)

E = Young's modulus of the material, psi 30×10^6

D = diameter to midplane of shell, inches. 108 inches

L = Unsupported length of shell plating inches 24 & 30 in.

t = 0.50 inches ⟶ up. (assumption)

when

$$t/D = 0.50/108 = 0.00463, \ (t/d)^{5/2} = 1.5(10^{-6}), \ (t/d)^{1/2} = 0.068$$

and $L = 24$ inches, $L/D = 24/108 = 0.222$

$$pc = \frac{2.6\ (30)\ 10^6\ (1.5)\ 10^{-6}}{0.222 - .45\ (0.068)} = \frac{117}{0.191} = \underline{\underline{612}} \text{ psi}$$

Since 700 psi is required the design is too light in buckling. For 0.50 inch thickness frame spacing (L) must drop to 21 inches. For 0.5625 (9/16) inch thickness frame spacing (L) may be 27 inches. Check 5/8" t at 30 inch frame spacing.

$$t/D = \frac{0.625}{108} = 0.00579, \ (t/D)^{5/2} = 2.6(10^{-6}), \ (t/D)^{1/2} = .076$$

$$L/D = \frac{30}{108} = 0.278$$

$$pc = \frac{2.6\ (30)\ 10^6\ (2.6)\ 10^{-6}}{0.278 - 0.45(0.076)} = \frac{202}{0.244} = 831 \text{ psi}$$

The design would be adequate in buckling.

(U) Deflection limitations imposed on the canister establish a need for a 0.75 inch thick skin. Assume that this thickness and a 30 inch ring spacing will prove adequate in shell yield and general instability. Verification can be accomplished by use of the (BOPS) program with the modified parameters. This would be in accord with the methods discussed in reference 3.

4.4.1.3 COMBINED STRESS

(DL) The canister skin may actually be subjected to bending stress, longitudinal compressive stress and lateral compressive stress simultaneously. The compressive stress due to bending has been calculated in section 4.1.1.1 as 21,000 psi. By adding the axial compressive stress due to water pressure on the canister ends the total axial compressive stress may be determined.

From:

dia. (max.)	109.5	inches
Area	9,420	in^2
Pressure (max)	700	psi
Circumference	342.5	in.
Skin thick.	0.75	in.

fa = axial compressive stress (water pressure)

$$fa = \frac{\text{Area x pressure}}{\text{Circumference x thickness}} = \frac{9420 \text{ in}^2 \times 700 \text{ lb/in}^2}{342.5 \text{ in.} \times 0.75}$$

fa = 25,670

adding $\underline{21,100}$ (bending stress)
46,670 psi (maximum axial compressive stress, S_1)
< 48,000 psi -- satisfactory in compression

(DL) By calculating the lateral compressive stress and combining this with the axial stress just calculated a check on the maximum principal stress (S_n) and the maximum shear stress (S_p) may be accomplished as follows:

From the 700 psi external pressure across the diameter of the canister the reactive compressive stress in the skin may be determined.

$$\frac{700 \text{ psi} \times 109.5 \text{ inch} \times 1 \text{ inch}}{2} = 38,250 \text{ lbs.}$$

(Reaction)

Approximately but accurately enough for preliminary design the cross sectional area of the reinforcing ring may be spread across the unsupported skin area and used in determining the skin stress.

$$\frac{\text{Area of reinforcing ring}}{\text{Length of unsupported skin}} = \frac{4 \times 0.75}{30} = 0.10 \text{ in.}$$

Skin (t) + 0.10 in. = 0.85 in. effective thickness

4.4.1.3 (Continued)

$$\text{Stress} = \frac{38,250 \text{ lbs}}{1 \text{ in.} \times 0.85} = 45,000 \text{ psi}$$

(lateral compressive stress, S_2)

(U) From reference 5, Table II case 4, the biaxial stresses can be combined to determine (S_n) and (S_p) the maximum principal and shear stresses.

$$S_n = S_1 \sin^2 + S_2 \cos^2$$

S_1 = 46,870 psi (max. axial compressive stress)

S_2 = 45,000 psi (lateral compressive stress)

$$\tan = \frac{S_2}{S_1} = 0.962 \qquad = 43° 53'$$

$\sin = 0.693 \qquad \sin^2 = 0.48$

$\cos = 0.721 \qquad \cos^2 = 0.52$

S_n = 46,870 (0.48) + 45,000 (0.52)

= 22,500 + 23,400

= 45,900 psi < 48,000 psi -- satisfactory

and the maximum shear stress from $S_p = 1/2\ (S_1 - S_2) \sin 2$

= 1/2 (1.870) (0.999)

= 935 psi. < 22,000 psi -- satisfactory

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4.4.2 ACCESS HATCHES

(U) One hatch is required at the top of the canister for launch and for installation of the missile. Hot launch requires that the bottom of the canister open to relieve gas pressure. Ease of missile installation and possible "in canister" maintenance also influence the need for a bottom opening on the canister.

(DL) Elliptical shaped heads with a major-to-minor axis ratio of two are proposed, a common practice for high-pressure bulkheads. (Reference 3, Chapter IV) The plating is designed to yield at test depth; the stiffeners are designed to yield at the specified collapse pressure of the pressure hull.

Using

$$t = \left[\frac{p\,D^2}{KE}\right]^{1/2} \quad \text{from ref. 3}$$

where

p = pressure at test depth. psi (466 psi)

D = radius of crown inches (100 inches)

K = 0.3 (from von Karmen and Tsien)

E = 30,000,000 psi

t = 0.72 inches minimum.

(DL) This corresponds to a thickness of 1.165 inches ($\sim 1\ 3/16$ inches) for an unstiffened shell as determined by the formula,

$$S_1 = \frac{p\,R_2}{2t} \qquad t = \frac{p\,R_2}{2S_1} \qquad \text{(reference 5, p. 269, case 5)}$$

in which

p = unit pressure psi (466 psi)

R_2 = radius of crown (100 inches)

S_1 = tensile yield stress psi (20,000 psi) (at S_1 =18,000 psi t=0.49in

(U) The 0.72 inch (actually 0.75 inch) thick plating with radial stiffeners will be used. A base ring to take the hoop stress will interface and seal with an end frame on the cylinder. The weight will approach:

Skin - 61 Ft^2 x 30.6#/Ft^2 = lbs. 1865

Stiffeners - 8 ea. x 10.5 Ft. x 10.2#/Ft. = 860 lbs.

Ring - 26.2 Ft. x 15.3#/Ft. = 400 lbs.

WT. STRUCTURE/PER LID = 3125 lbs

4.4.3 MECHANISMS

(U) The lids will be dogged similar to the lids of the Polaris boat launch tubes. The top lid only will be hinged (reference appendix B) and the lower lid will be permitted to fall free when released. Actions required to open the lids are:

Break seal between lid and cylinder.

Rotate the lid.

Lift the lid (top lid only, bottom releases due to internal pressure)

Swing lid open (top lid only)

Assume the forces holding the lid to the cylinder are rust and friction.

Circumference of Lid = π (106 in.) = 333 in.
Area of lid = $\frac{\pi (106)^2}{4}$ = 8820 in^2

External Pressure at start of rotation -

depth x 0.444 psi/ft	~	44.4 psi
Internal Pressure - Assume		24.4 psi
Δ p		20.0 psi

Total pressure = 8820 in^2 x 20 = 17,640 lbs

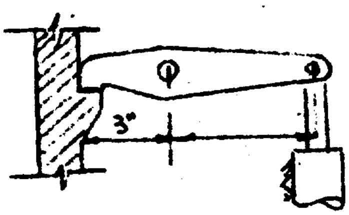
x Cf (0.2) = 3528 lbs Rusty Surface

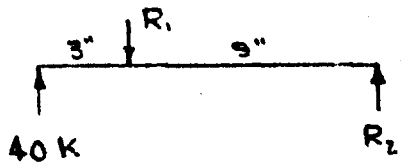
Assume rust on 2" ring at circumference produces an ultimate shear of 50 psi.

Circumference x 2 inch width x 50 psi =	33,300
plus friction	3,528
Breakloose force	36,828 lbs
Rotating force	3,528 lbs

Design for 40,000 lbs.

Using a lever driven by a hydraulic cylinder to break the seal and rotate the lid.





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For a hinge pin 3 inches above the hub.

R_1 = 40K x 12/9 = 53,300 lbs.

R_2 = 40K x 3/9 = 13,300 lbs.

Beam Moment = 40K x 3 in. = 120 in-kips

$$fs = \frac{6M}{bh^2}$$

$$h = \sqrt{\frac{6M}{fsb}}$$

for b = 1.5 and fs = 30 ksi

h = 4

Pin Shear = 53,300 lbs. Single shear allow 20,000 psi

Pin Area = 53,300/20,000 = 2.67 in^2 ~ 2 in. dia.

Pin Bending Moment = 53,300 lbs x 0.75 in = 40,000 in - lbs.

$$I_{pin} = \frac{\pi}{64}(2)^4 = 0.785 \text{ in}^4$$

$$fb = \frac{40,000 \times 1}{0.785} = 51,000 \text{ psi}$$ (too high)

Try 2-1/2 in. dia pin.

I = 1.917 f_b = 26,000 psi - OK

Cylinder (3000 psi oil) Area = 12,300 lbs/3 = 4.5 in^2

use 2-1/2 i.d., hydraulic cylinder.

(U) Additional calculations to size the lifting arm, the lifting hydraulic cylinder, etc., produce an arm approximately the size of a 6-inch by 8-inch WF and a 3-3/8 in. diameter hydraulic cylinder. Sizing of other components has been done but will be omitted in the interest of brevity.

4.5 SUSPENSION SYSTEM

(U) The primary function of the suspension system is to safely position the missile in the canister during all modes of operation whether at sea or on land. In so doing, the suspension system is required to cushion the missile from excess shock levels and to reposition it in the canister after relative movements. It may also be required to provide hot gas and acoustic shielding of the missile at missile launch.

(U) From the environmental design requirements defined in Section 3.2 and Appendix B the canister is required to attenuate weapon effect shock loads along any of the 3 major axis to levels tolerable to the missile. These levels were arbitrarily established at $\pm$ 6.0 G's along the longitudinal axis and $\pm$ 3.0 G's laterally.

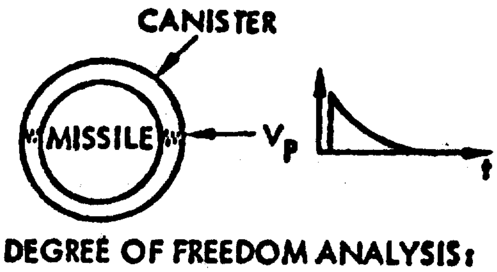
(U) Design load analysis at this stage of design warrants only basic static load computations and a simplified dynamic analysis. The dynamic analysis assumes a single degree of freedom system in which the can is the foundation for a spring mass, the missile, and moves with the particle velocity of the water. The "G" response of the missile is related to the spring stiffness between the canister and the missile. As noted in reference 6 regarding the Polaris support systen, 'the shock motion is relatively severe, the missile is fragile and a very low-frequency mount is required to protect the missile during "near-miss" underwater explosive attack.' The same situation is true for ULMS. Figure 4-16 relates rattle space requirements to weapon effects (peak particle velocity in ft. per sec.), "g" levels and predicted frequencies.

4.5.1 LATERAL SUSPENSION SYSTEM

(U) Three types of lateral suspension systems were investigated; restrained coil springs appeared to require excessive volume, to be difficult to install, heavy and more expensive than an air bag system. No feasible liquid spring system appeared to satisfy the requirements of the system. Two conceptual designs utilizing air bags appeared feasible. As depicted in Appendix A these are "Air Mat" ▷1 bags between the canister and a liner (launch tube) containing the missile and "Air-Mat" bags with a stiff reinforced rubber seal. Sample calculations are presented in the following paragraphs to show typical air-bag pressures at static and dynamically loaded conditions.

(U) From Fig 4-17 assuming the five point support (BDEFG) the static reaction from the missile at G is approximately 61 kips. Adding 3000 pounds for the liner and 1500 pounds for the support ring the static loading at G is 65.5 kips on the air bags. The dynamic load at 3 G's would add 196.5 kips for the worst case of 262.0 kips. Fig. 4-18 shows the proposed arrangement of air bag suspension system with a liner. The bearing area per air-bag is $\frac{92" \times 25.25"}{144} = 16.1\ ft^2$ per ring in the static load condition. It is approximately 17.4 ft^2 per ring when compressed 4 inches. The volume per segment in the static load condition is

▷1 Goodyear Aerospace Division - Trade Name



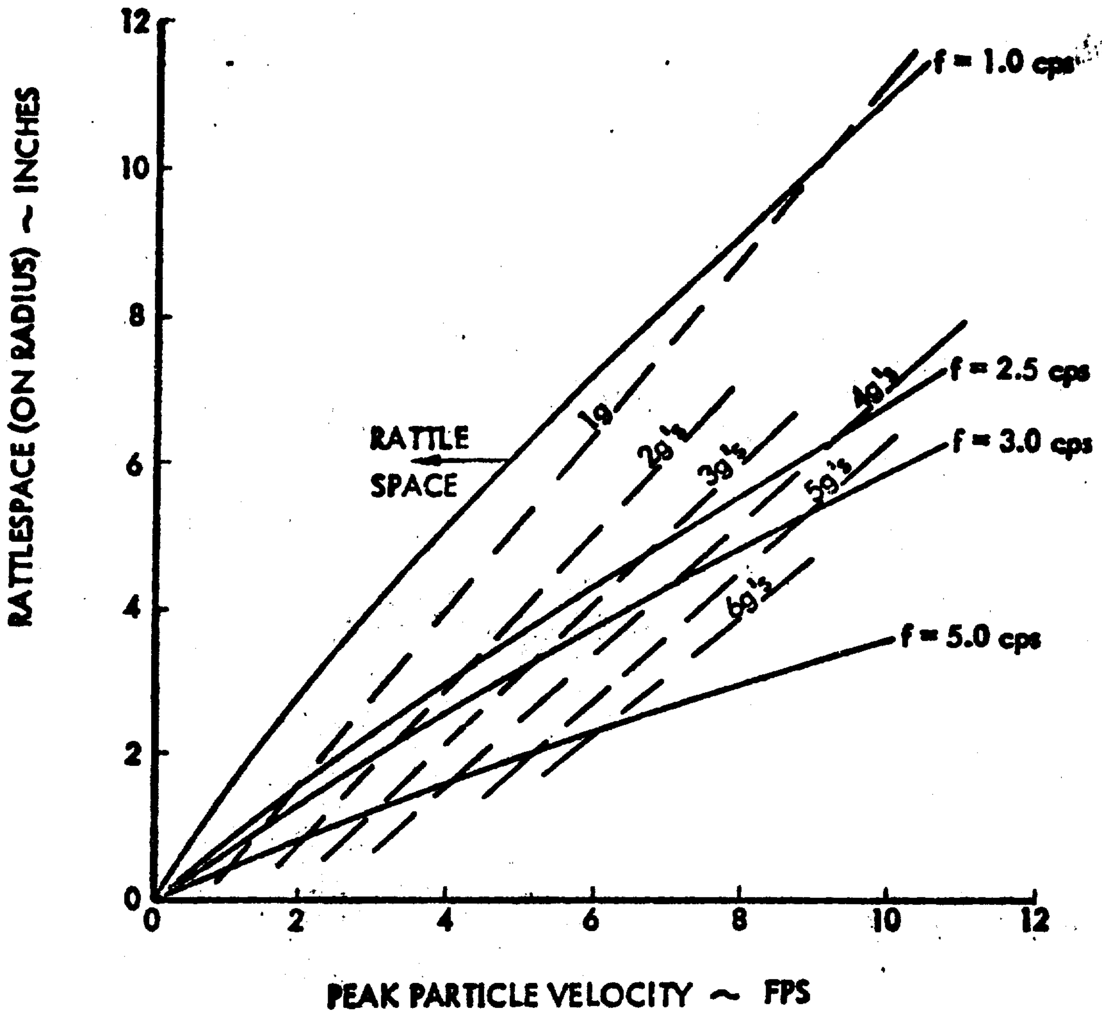


Figure 4-16 CANISTER RATTLESPACE REQUIREMENTS VS WEAPONS EFFECTS (PEAK PARTICLE VELOCITY) AND ALLOWABLE MISSILE "G" LOADS

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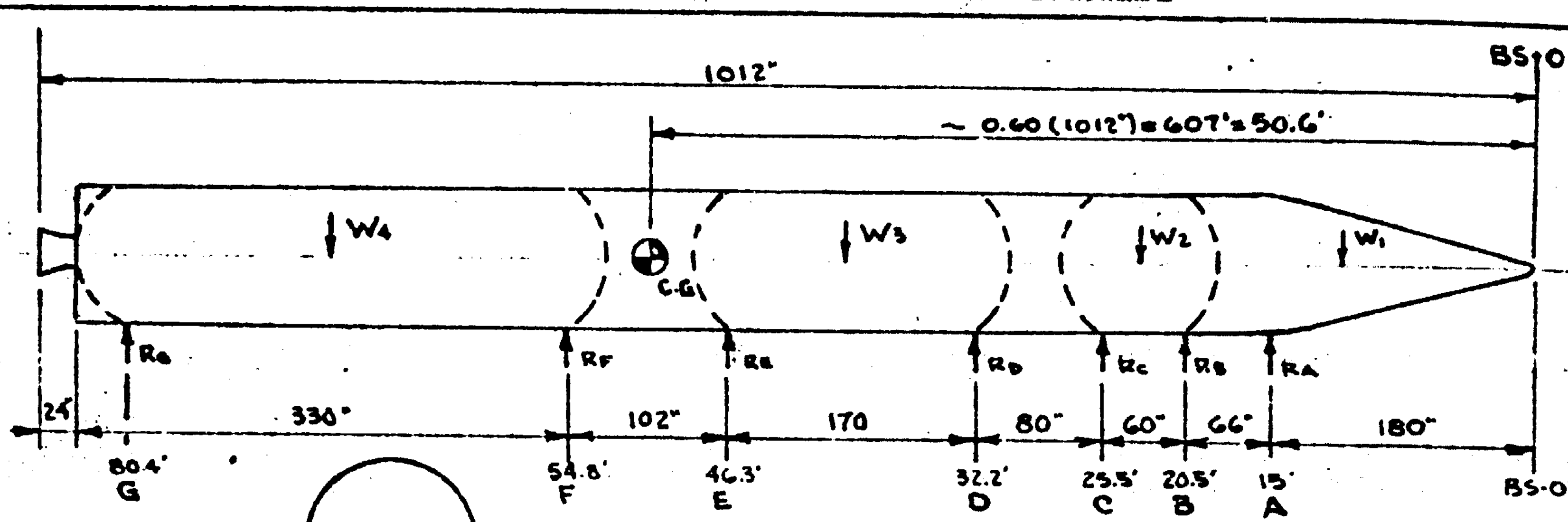

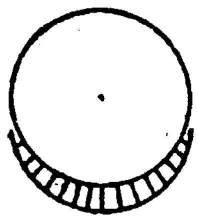

LOAD SHAPE
REF. 5

	ESTIMATED WEIGHT LBS.	DISTANCE FROM BS-0	MOMENT FT-LBS x 10^3
W_1	6,000	11 FT.	66
W_2	34,000	22	748
W_3	70,000	39	2,730
W_4	115,000	68	7,820
$W_{C.G.}$	225,000	50.6	11,364

APPROXIMATE REACTION LOADS (IN KIPS)

SUPPORT POINTS	R_A	R_B	R_C	R_D	R_E	R_F	R_G
AEG	50	–	–	–	105	–	70
BEG	–	50	–	–	112	–	63
ACEG	14.5	–	43	–	105	–	62.5
ACFG	14.5	–	43	–	–	135	32.5
BEFG	–	50	–	–	60	(-78.3)	193.3
ACEFG	14.5	–	43	–	35	277	(-144.5)
ADEFG	40	–	–	31.5	38.5	54	61
BDEFG	–	33	–	38.5	33.5	54	61
ABDEFG	99	40.5	–	21	38.6	54	61

Figure 4-17 MISSILE SUPPORT CONDITION REACTIONS

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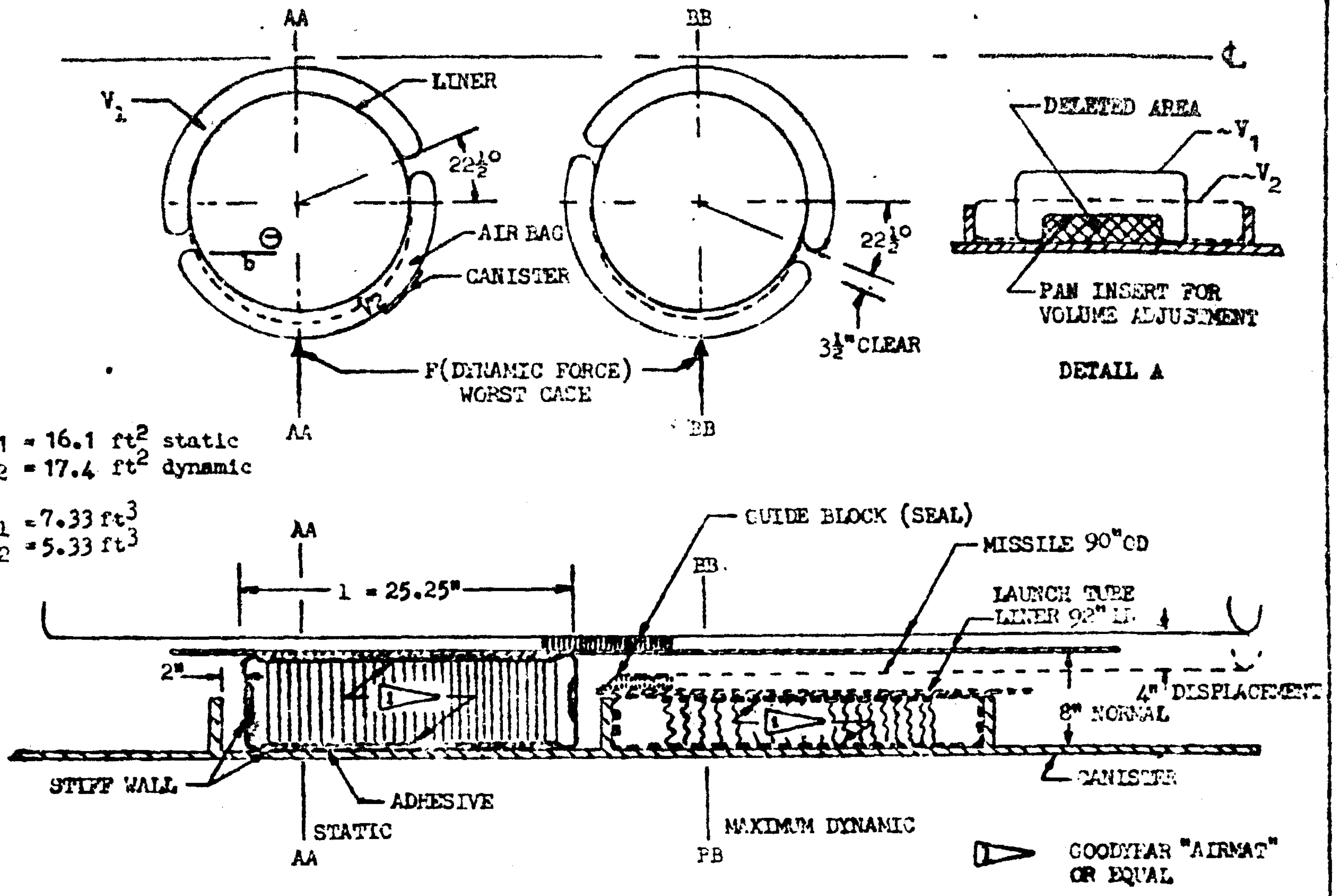


NOTE:
A_1 = 16.1 ft^2 static
A_2 = 17.4 ft^2 dynamic

V_1 = 7.33 ft^3
V_2 = 5.33 ft^3

Fig. 4-18 AIR BAG-LINER -SUSPENSION SYSTEM

4.2.1 Continued

7.33 ft^3 (V_1). The volume when compressed under dynamic load is approximately 5.33 ft^3 (V_2).

(U) Assuming a two ring support area the pressure at dynamic loading is

$$P_2 = F/A_2 = \frac{262{,}000 \text{ lbs}}{34.4\ (144)} = 52.9 \text{ p.s.i.g.}$$

This is an acceptable pressure for "AIR-MAT." As a preliminary estimate and considering the compression cycle to be isothermal in which $P_1 V_1 = P_2 V_2$ then

$$P_1 \approx \frac{P_2 V_2}{V_1} \approx \frac{52.9\ (10.66)}{14.66} \approx 38.5 \text{ psig}$$

Checking - $F_1 = P_1 A_1$

$$A_1 = 2(16.1) = 32.2 \text{ ft}^2$$

therefore $F_1 = 38.5 \text{ lbs/in}^2 \times 144 \text{ in}^2/\text{ft}^2 \times 32.2 \text{ ft}^2 = 178{,}500$ lbs.

$>$ static load of 65.5 kips.

It would support the missile but probably would be stiffer than desired. Once the desired spring rate is determined then the ratio between P_2, P_1, V_1 and V_2 can be established. For instance, if it is desired to set $P_2/P_1 = 3$ then V_1/V_2 must approach 3. This can be accomplished by installing a pan insert in the area commonly occupied by V_1 and V_2 such that the V_1/V_2 ratio is adjusted. (Detail A, Figure 4-18).

(U) Second cut calculations showing temperature effects on pressure ($P_1 V_1/T_1 = P_2 V_2/T_2$) are necessary before selection of design P_1 is made. Temperature ranges may be selected from environmental requirements. Selection of air bag sizes to provide uniform pressure and/or spring rate response at each missile support location is a continuation into detail design not required in this document.

(U) Additional factors to be considered are the effects of longitudinal displacements on the air bag system and vice-versa. "Oil canning" of the liner due to pressure of the unsupported air bags away from the guide block could be a problem. Tolerance of air mat construction thickness ± 1/16" will be additive to other tolerances to determine worst case displacement off center at each support. Material for the seals must be resistant to creep or cold flow and have a low coefficient of friction. Development testing is assumed.

(U) Design of an air bag suspension system design (no liner) is essentially the same as the liner system except that seals must be incorporated to prevent acoustic and hot gas blow by during launch. Study of the launch gas forces to provide retention of the air bags during launch is required. A method of releasing the air bag pressures to permit launch of the missile is also required. Careful material selection to prevent adhesion of the air bag to the missile is required.

4.5.2 LONGITUDINAL SUSPENSION SYSTEM

(U) The primary function of the longitudinal suspension system is to position the missile longitudinally in the canister during sea and land operations. The 6 "g" tolerance of the missile along this axis requires that, to prevent missile damage, shock in excess of this be attenuated by the suspension system. From weapon threat and effects studied in Reference , a 2-inch maximum displacement along the longitudinal axis provides this attenuation.

4.5.2.1 CONCEPT DEVELOPMENT

(U) To make the longitudinal suspension system work the missile must be "locked" into the system with provisions for release at launch. A support ring at the base of the missile skirt can provide restraint against relative motion in the aft direction. If the missile can withstand tension, a locking device attaching the missile skirt to the support ring could provide the necessary relative forward restraint. Another method of providing forward restraint would make use of the liner proposed in the lateral suspension system: blocks at the shoulder of the missile would be locked to the liner and released prior to launch.

(U) The longitudinal suspension system must allow free movement of the lateral suspension system and attenuate fore and aft shock. Absorption of shock is normally accomplished with a spring-shock absorber system. Several types were considered including restrained springs, rubber compression or shear mounts, Houdaille snubbers and Minuteman type liquid and pneumatic spring systems. Because these systems require more space than is available in the narrow canister confines, alternate systems have been investigated. Two candidates show promise; a system of annular cables and a Belleville Spring System (Figure 4-19)

4.5.2.2 ANNULAR CABLE SYSTEM

(U) The annular cable suspension system shown consists of 100-3/8" (approx) cables for the forward motion restraint and 100-3/8" cables for the aft motion restraint. The sketch as drawn would use a lock in system at the missile skirt but the shoulder-block locks with a liner could be used just as well by including the deformation of the liner in the forward restraint system. The liner under a 6 g load would be stressed to about 27,700 psi and would stretch about 0.77 inches.

(U) A modification to this system could be designed to shorten the cable system. An elastic ring could be sized to put a knee or curve in the longitudinal cables to provide a greater spring rate in less cable length (i.e., about 48 inches). It would supply pre-tensioning to the cables to prevent the suspended mass from impacting a slack system.

USE FOR TYPEWRITTEN MATERIAL ONLY

U3 4802 1434 REV. 8-65

USE FOR DRAWING AND HANDPRINTING — NO TYPEWRITTEN MATERIAL

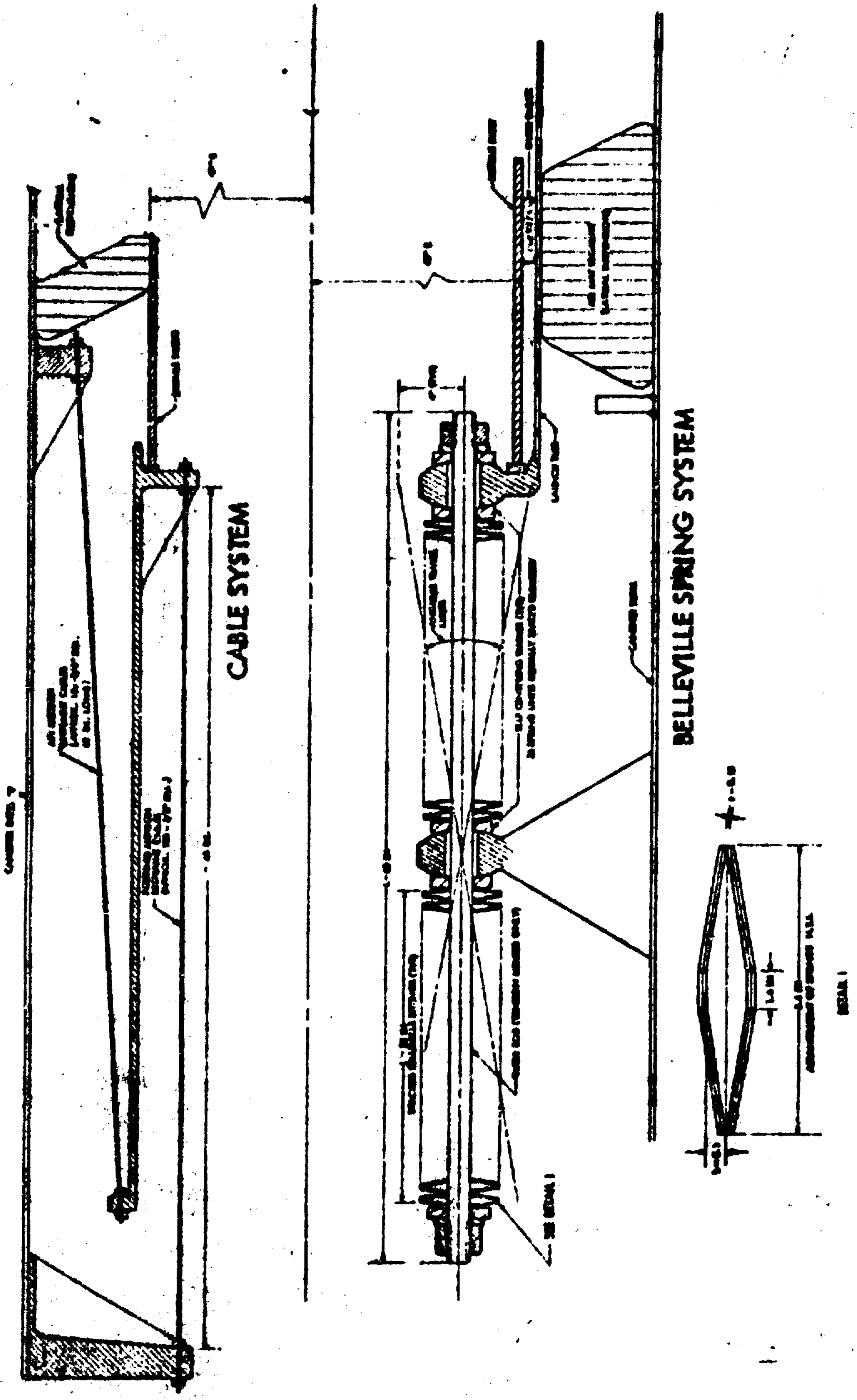


Figure 4-19 PROPOSED ULMS LONGITUDINAL MISSILE SUSPENSION

4.5.2.2 (Continued)

(U) Design of the cable system utilizes the material modulus of elasticity (E) to develop the spring rate.

(U) From the graphs (Figure 4-20 through Figure 4-24) it can be seen that the lower the modulus of elasticity (E) and the higher the design stress, the shorter the length of cables and the less the cross-section area of stressed fibers are necessary. For straight steel wire, the length becomes practical only if the working stress is in the order of 300,000 psi. Steels are available in this category (see Figure 4-20). The smaller the diameter of wire the higher the working stress.

(U) Phosper-bronze spring wire per Figure 4-21 has an E of about half that of steel and provides more springiness. The strength is about half that of steel so that the length required is the same as the all steel wire system. The cross-sectional area of the non-ferrous system would be twice that of the ferrous system. The density of phosper bronze is greater than steel (about 15%). The weight of the system would be over twice that of steel. The non-ferrous system may be more resistive to corrosion; however, the cost would be greater. Further study could discover the advantages and disadvantages of a non-ferrous system.

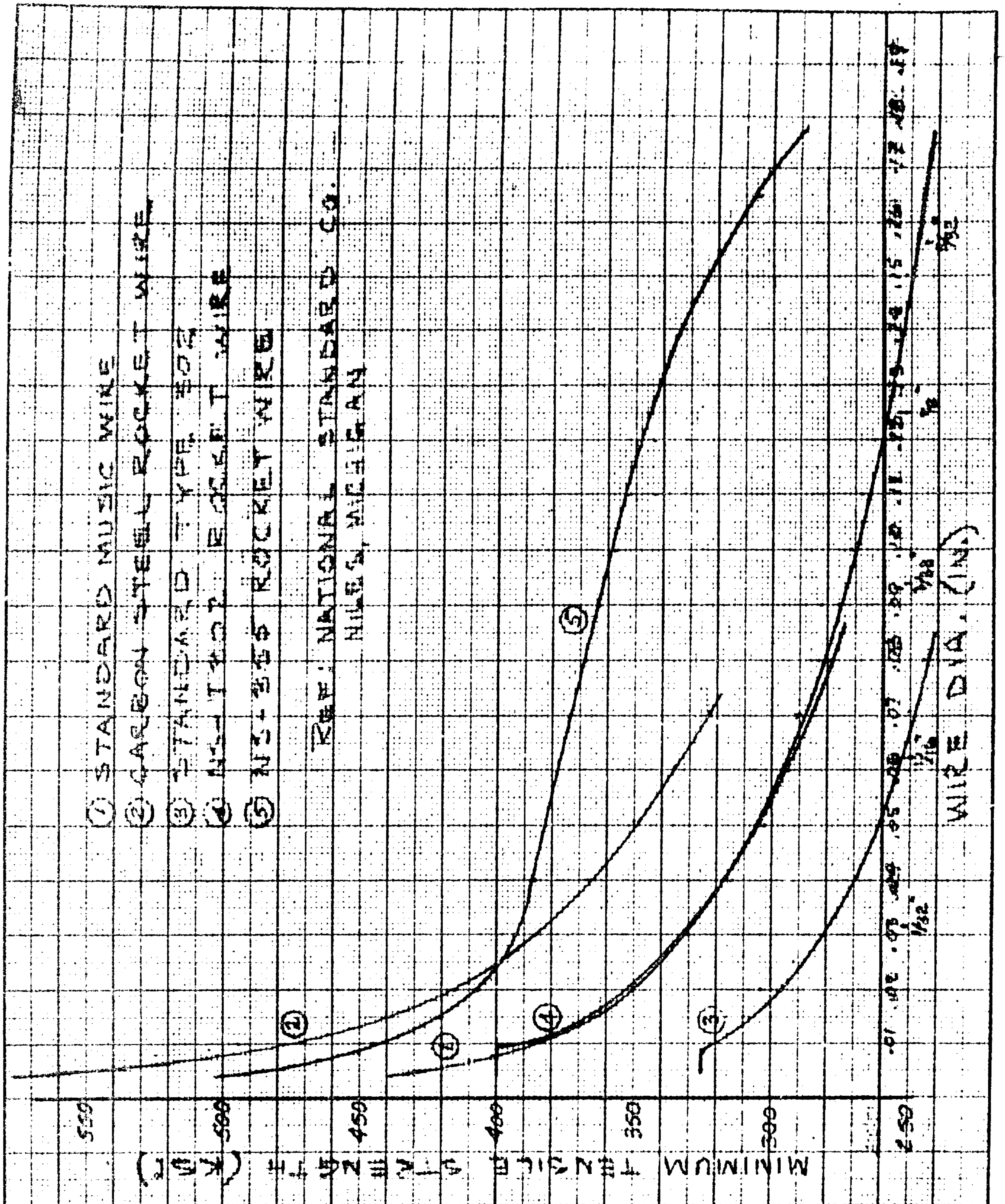
(U) A non-ferrous cable system as opposed to a straight wire system may be superior to a steel cable system. No precise engineering data could be found on the elastic properties of a non-ferrous cable. Some weight and strength data is included in this report. The E of phosper bronze cable must be inherently low but the strength is also low compared to steel and there appears to be no gain in using the non-ferrous system.

(U) Most plastics tend to take on a permanent or temporary flow at a very small percentage of their breaking strength (generally around 4%). Their characteristics also vary widely with temperature and humidity changes making their operative repetiveness unreliable. Nylon appears to be one of the more stable plastics temperature wise. However, it is not recommended beyond about 10% of its breaking strength. The breaking strength is in the order of 10 - 15,000 psi depending on the type of nylon. The required length and cross sectional area makes it a poor candidate for the subject application.

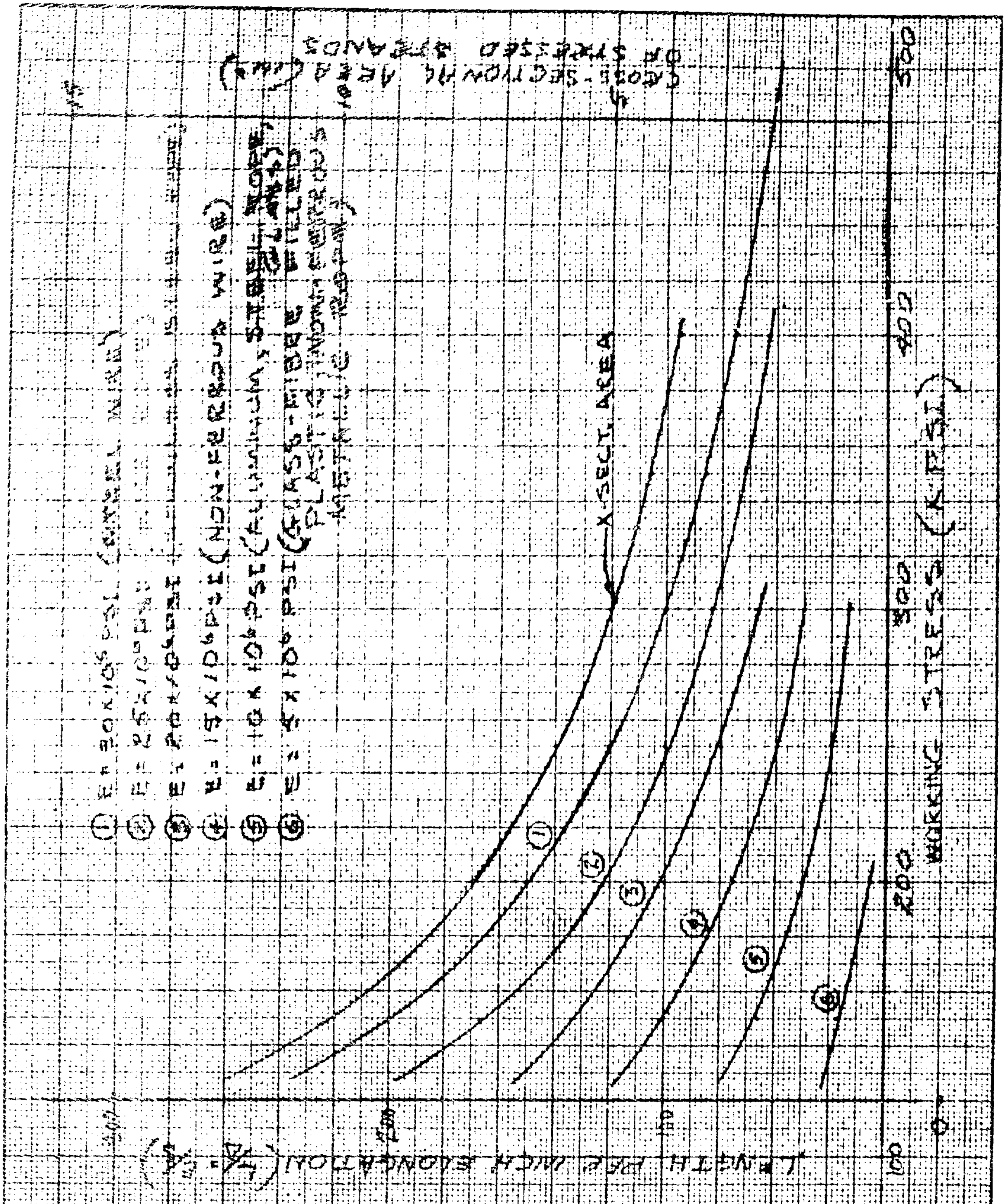
(U) One family of materials that may be a serious candidate is parallel glass-fibre filled plastic. Some articles give a modulus of elasticity of 3 - 6,000,000 and a design stress of 120 - 150,000 psi. The resulting system has a high volume efficiency compared with all other materials. The weight of the system would be much less than any other system. (The subject system is much more volume critical than weight critical.)

4.5.2.3 BELLEVILLE SPRING SYSTEM

(U) Figure 4-19 shows a preliminary design which satisfies the longitudinal suspension system requirements. Belleville Springs are stacked in parallel and series combinations on rods mounted circumferentially between the launch tube and the canister. Motion between the launch

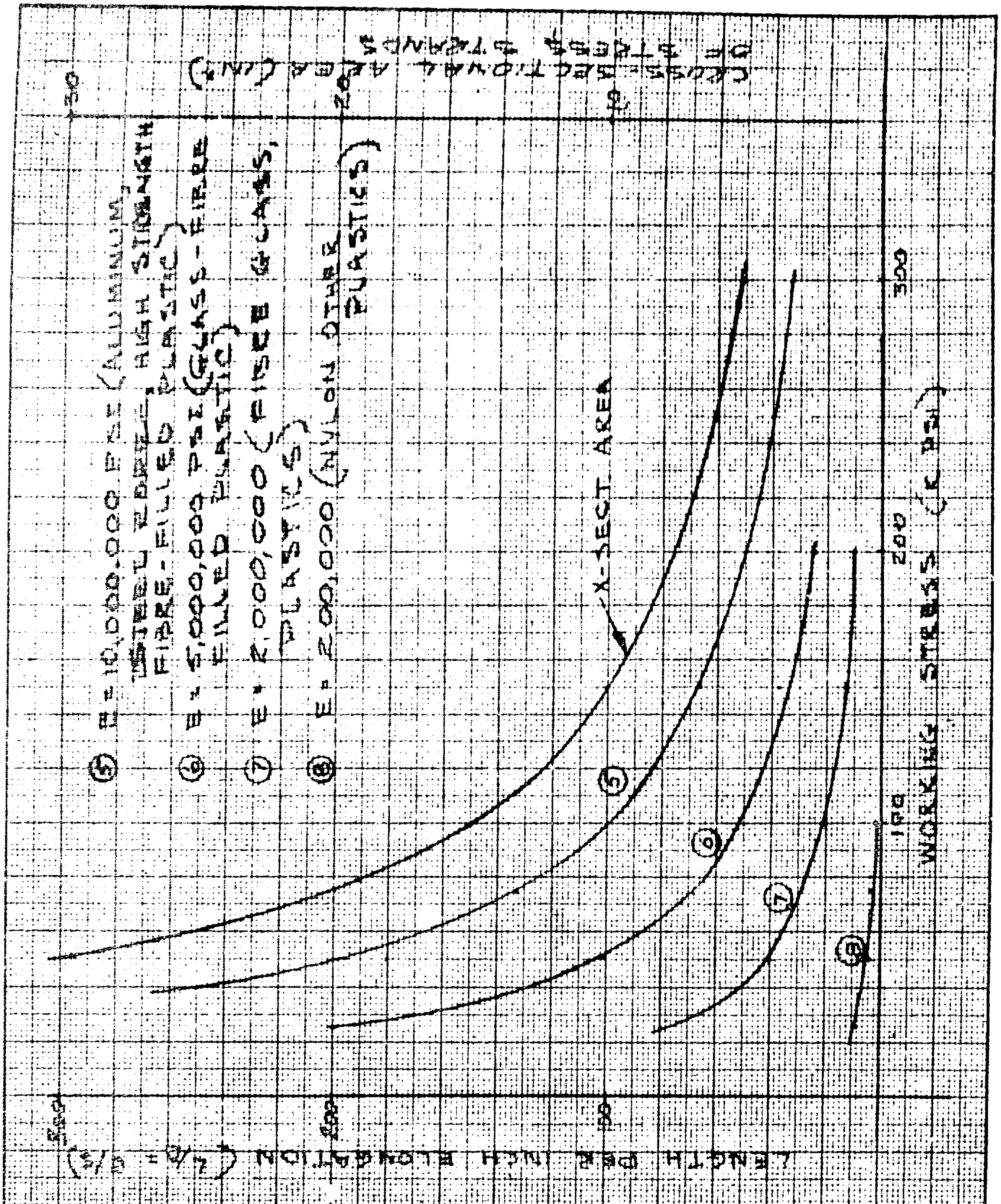


	INITIALS	DATE	REV BY INITIAL	DATE	TITLE	MODEL
CALC	[signature]	8/29/?			SPRING WIRE PROPERTIES	Figure 4-10
CHECK						
APPD.						
APPD						



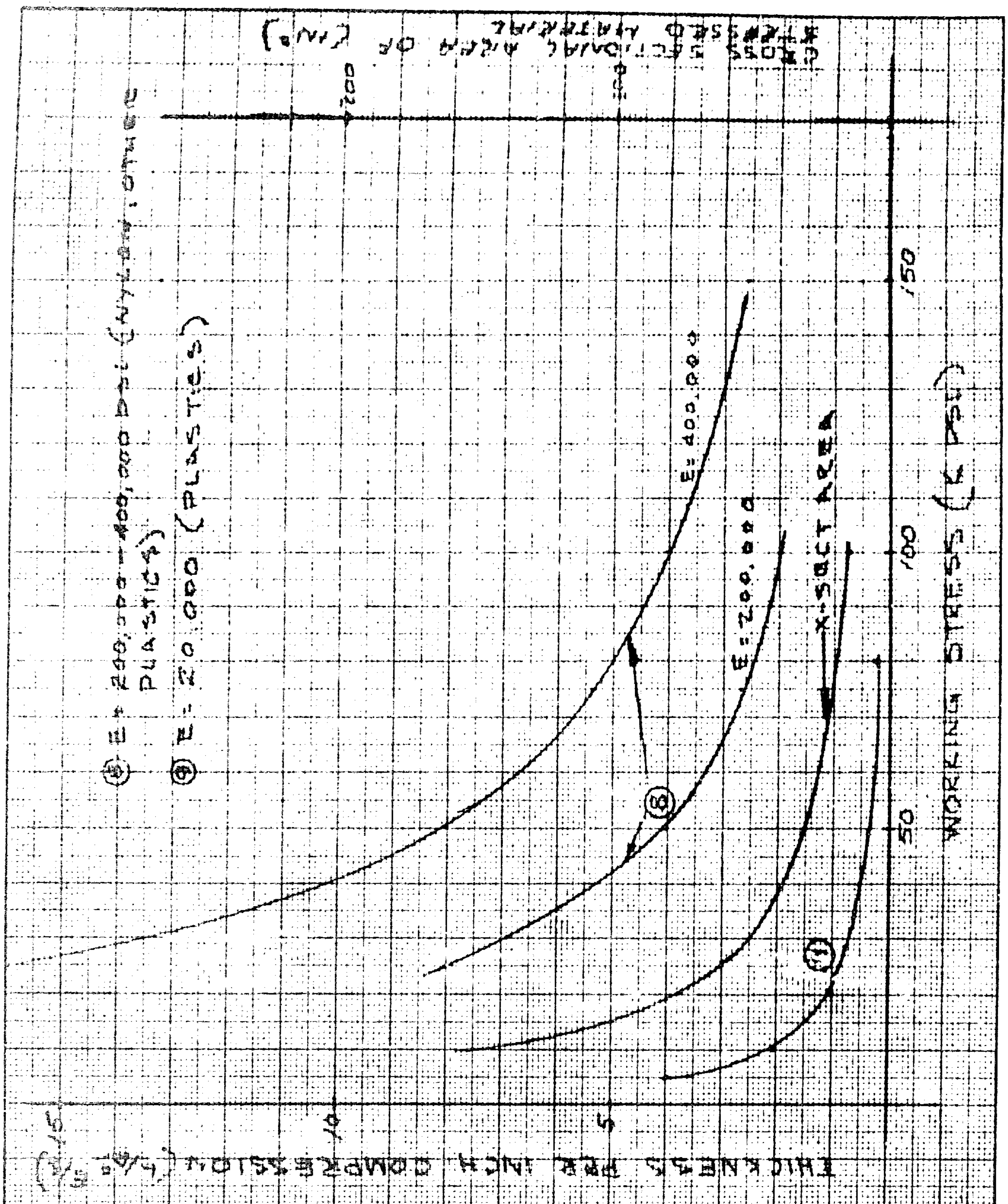
	INITIALS	DATE	REV BY INITIAL	DATE	TITLE	MODEL
CALC	[illegible]	5/29/9			CROSS SECTIONAL AREA AND LENGTH VS WORKING STRESS	Figure 4-21
CHECK						
APPD						
APPD						

REV LTR



	INITIALS	DATE	REV BY INITIAL	DATE	TITLE	MODEL
CALC		8/29/9			CROSS SECTIONAL AREA AND LENGTH VS WORKING STRESS	Figure 4-22
CHECK						
APPD.						
APPD						

REV LTR



	INITIALS	DATE	REV BY INITIAL	DATE	TITLE	MODEL
CALC	4fw	8/29/9			CROSS SECTIONAL AREA AND THICKNESS VS WORKING STRESS	Figure 4-23
CHECK						
APPD						
APPD						

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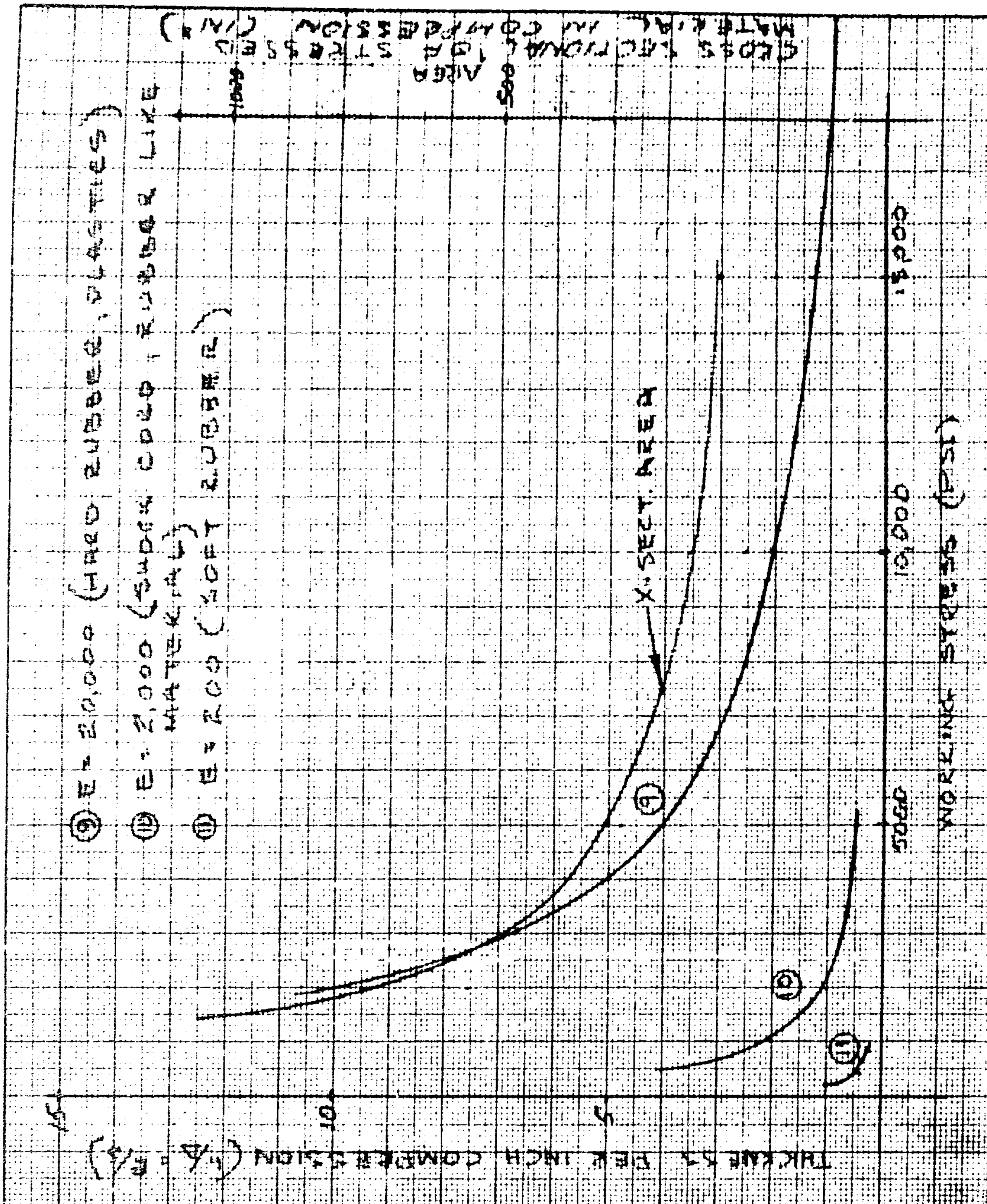
REV LTR



	INITIALS	DATE	REV BY INITIAL	DATE	TITLE	MODEL
CALC	[illegible]	8/29/?			CROSS SECTIONAL AREA AND THICKNESS VS WORKING STRESS	Figure 4-24
CHECK						
APPD						
APPD						

4.5.2.3 (Continued)

tube and the canister is attenuated by compression of the springs and friction in the spring system. The rods act as guides for the springs and as tension members when the motion of the launch tube is away from the support ring on the canister. Self-aligning spherical washers transmit the forces between the springs and bosses on the structural members while providing clearance for the rod to accommodate the plus or minus 4 inch lateral motions required. See Reference 7 for design procedure.

Characteristics of the Belleville Spring System

(U) Two inch plus or minus longitudinal motion is possible in the available space with appropriate design effort. Weight is approximately 7500 pounds for the spring system with each spring unit being slightly over 200 pounds. The weight in this location aids in pulling the overall canister c.g. toward the bottom end, to help produce proper transit and launch attitude. Materials are 1095 steel at various heat treatments. Installation and maintenance, if any, are simple.

4.6 SUBSYSTEM DESIGN

(U) This section discusses the assumptions of the designer regarding the canister subsystems.

4.6.1 ELECTRICAL

(U) The electrical subsystem is required to provide circuits and components for control, monitor and power to the missile, the environmental control subsystem, the hydraulic subsystem and the pneumatic system. Additionally the depth sensors and timers used for lower canister ballast control and initiation of the launch sequence are parts of the electrical subsystem.

(U) Primary power would be furnished via the submarine to canister umbilical. Power required during the transit mode prior to launch would make a battery aboard the canister mandatory. The electrical subsystem does not appear to present any major problems.

4.6.2 ENVIRONMENTAL CONTROL

(U) The environmental control subsystem is required to maintain the missile environment within limits. The missile is generally dormant and submarine deployment areas can range between frigid artic waters and warm tropical waters. Both heating and cooling are required as is insulation on the canister shell. Preparation of the canister for sea would include humidity control. Possibly the canister would be filled with an inert gas.

(U) The details of the environmental control system have not been worked but the requirements appear to be a matter of application of existing types of equipment. Heat loss could be a problem in frigid waters.

4.6.3 HYDRAULIC

(U) The hydraulic system is used to undog the canister lids, and to open the top lid at launch (reference Figures 4-5 and 4-7). The submarine hydraulic systems will provide the unlatching force for canister release.

(U) The system will operate at 1300 psi which is compatible with present Navy use. Standard components will be used throughout the system.

4.6.4 BALLAST

(U) For proper launch of the missile the velocity of the canister at broaching needs control. Too much speed and the canister rises too far out of the water and becomes unstable. To maintain a plus 4 to 7% positive buoyancy, internal ballast pigs will be installed around the inside periphery of the can aft of the missile tail. Testing may establish a requirement for deployment of a droque during transit.

USE FOR TYPEWRITTEN MATERIAL ONLY

(U) Negative buoyancy is required for bottom release canisters so that their trajectory pulls them away from the submarine at the time of release. As shown in Figure 4-9 an external ballast disc is attached to the aft dome of the canister. About 25,000 lbs. is needed and a molded cast iron disc 7.5 ft. in diameter by 1.5 ft. thick would satisfy the weight requirements. Release may be by squib or hydraulics.

4.6.5 PNEUMATIC SYSTEM

(U) Potential requirements for a dwell (hover) mode for the canister may establish a need for a pneumatic system. No details have been worked but sea water ballast and volume control may make this dwell mode impractical for the proposed canister design.

4.6.6 CORROSION RESISTANCE

(U) Surface coating and cathodic protection will be used on the main structure of the canister. Details of the design at moving parts such as the lid dogs and the trunnion have not been established but are not expected to be problem areas.

5 CONCLUSIONS

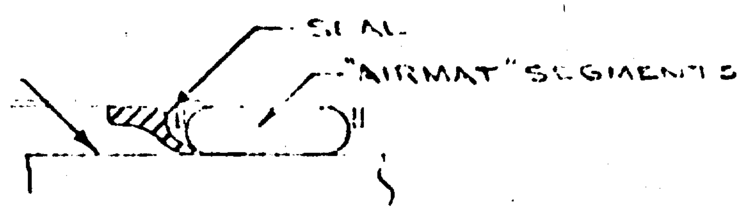
(DL) Design and construction of undersea canisters for launching large missiles in the 225,000 lbs. class appears feasible and within the state-of-the-art. Such canisters can be designed to be launched from submarines travelling at speeds in excess of 10 knots.

(U) Since this canister was deflection critical rather than stress critical, optimization programs such as BOPS should provide for incorporation of deflection inputs.

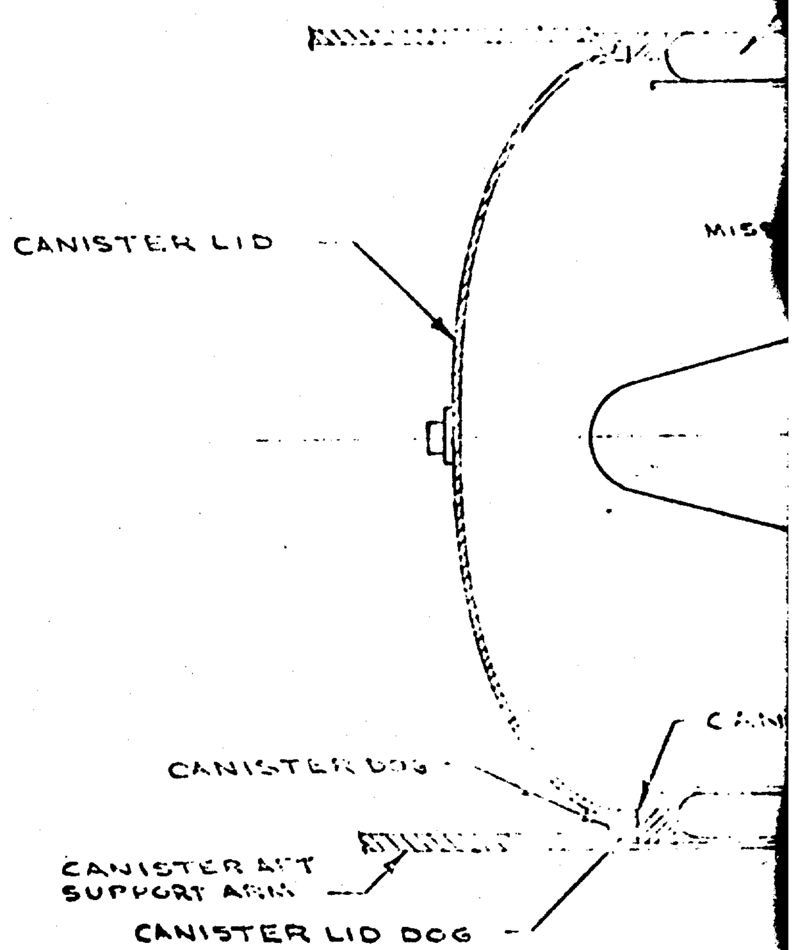
(U) An air bag system provides a satisfactory means for lateral suspension and shock displacement attenuation.

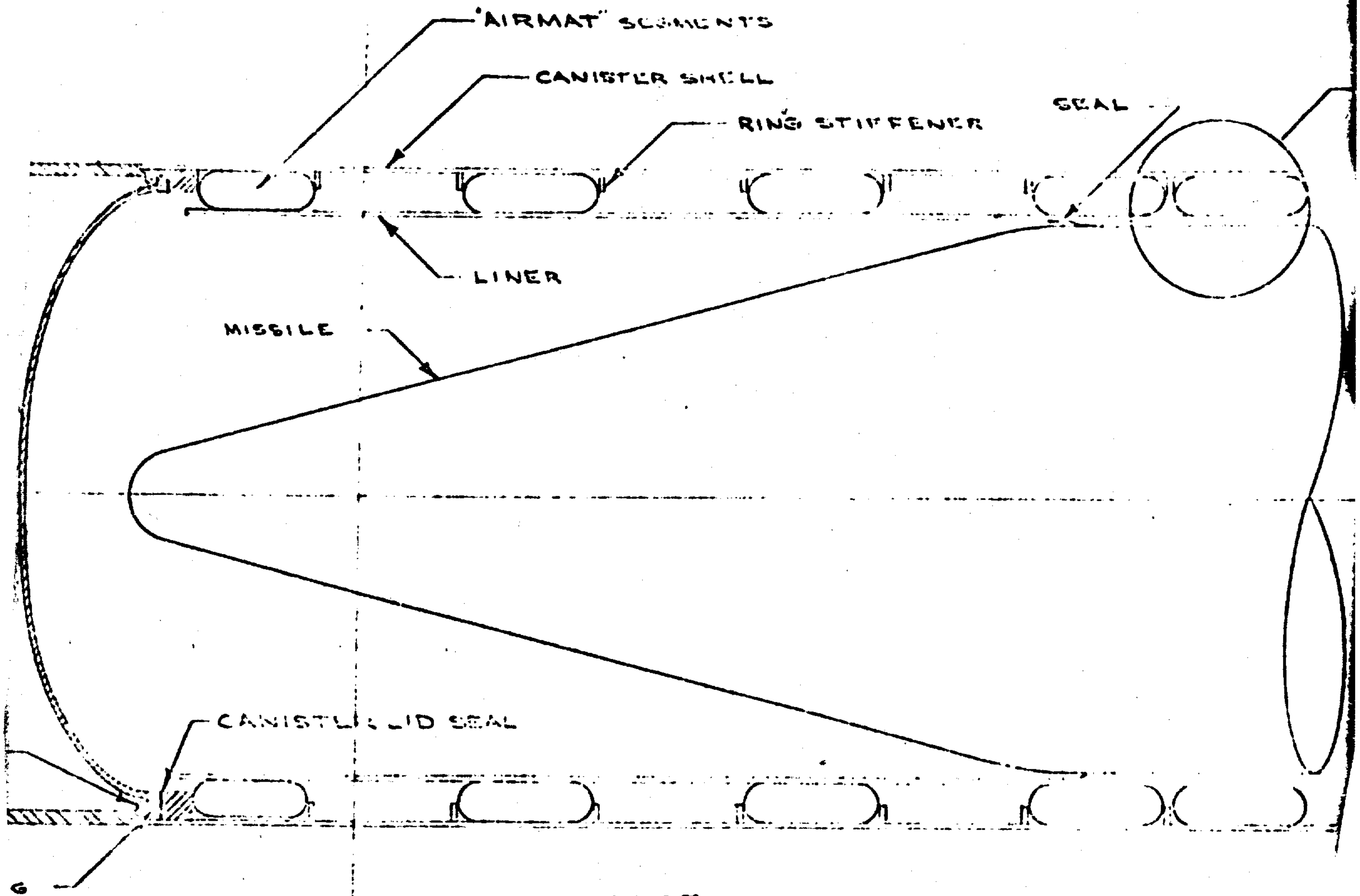
(U) Longitudinal suspension and shock displacement attenuation can be accomplished by several systems including a belleville spring system or a cable system.

(U) Development of canister subsystems with the exception of a dwell (hover) subsystem is not expected to present difficult design problems.

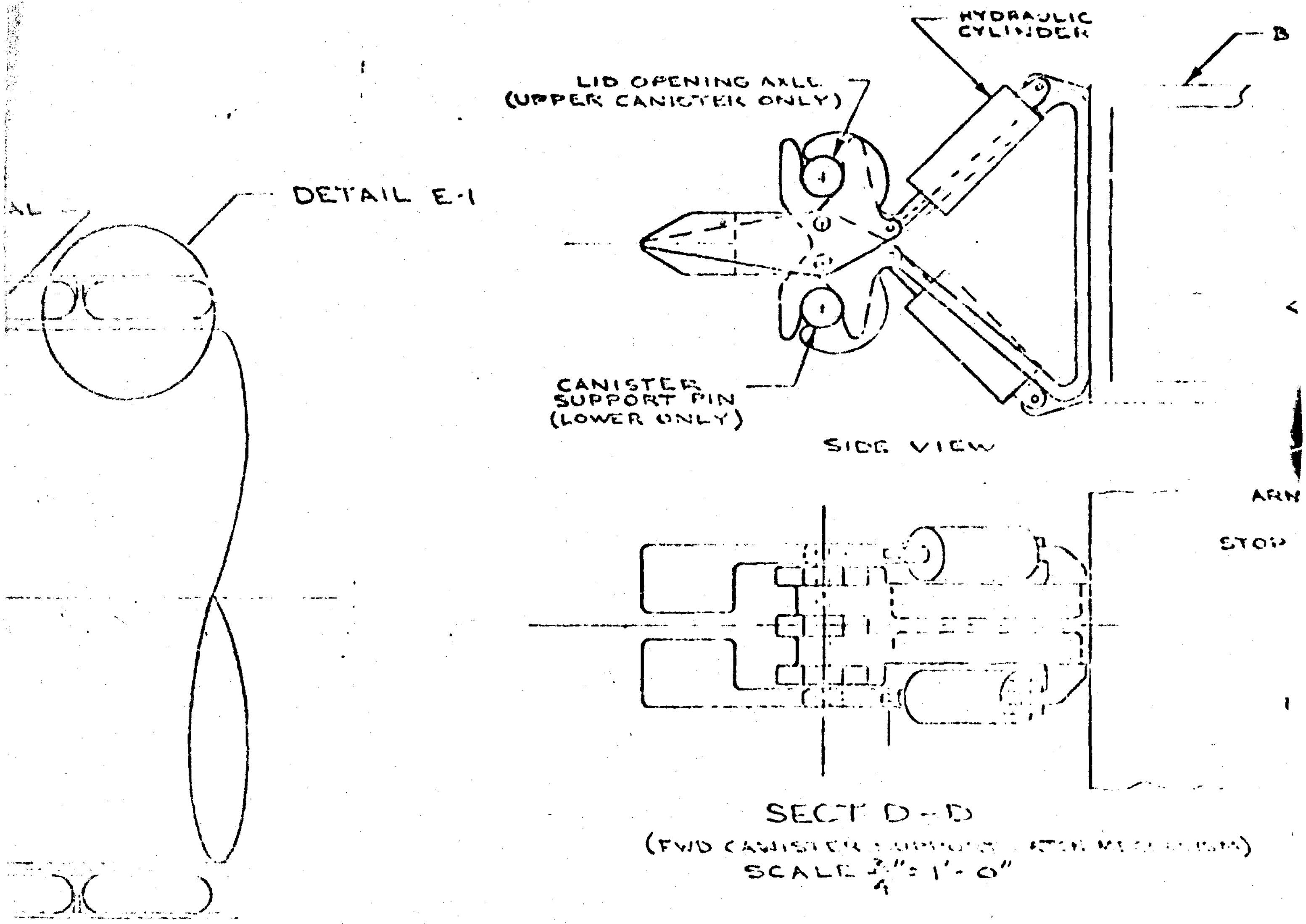


DETAIL E-1
ALTERNATE SEAL DETAIL
WITH NO LINER

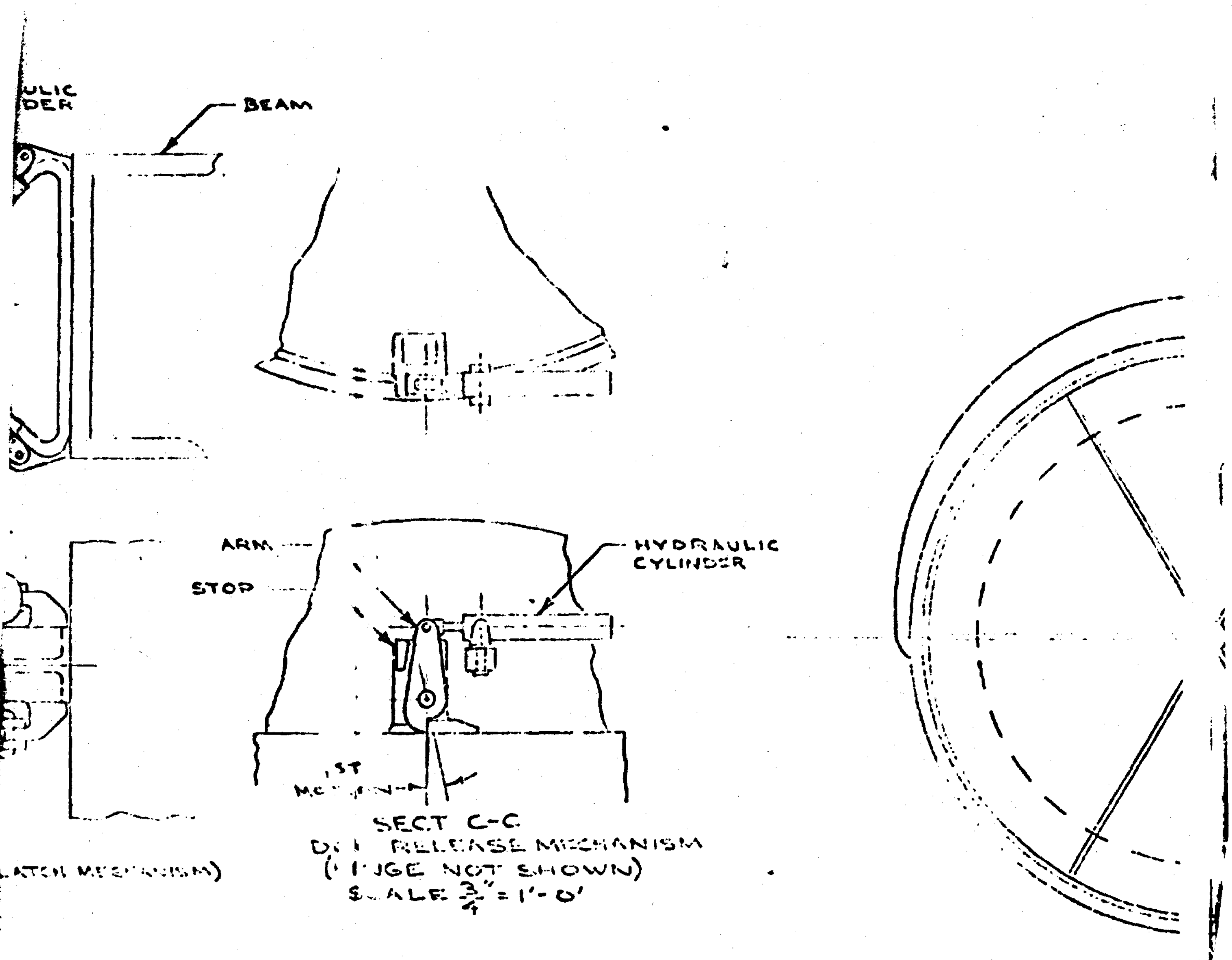




SECT E-E
SCALE $\frac{1}{2}$"=1'-0"

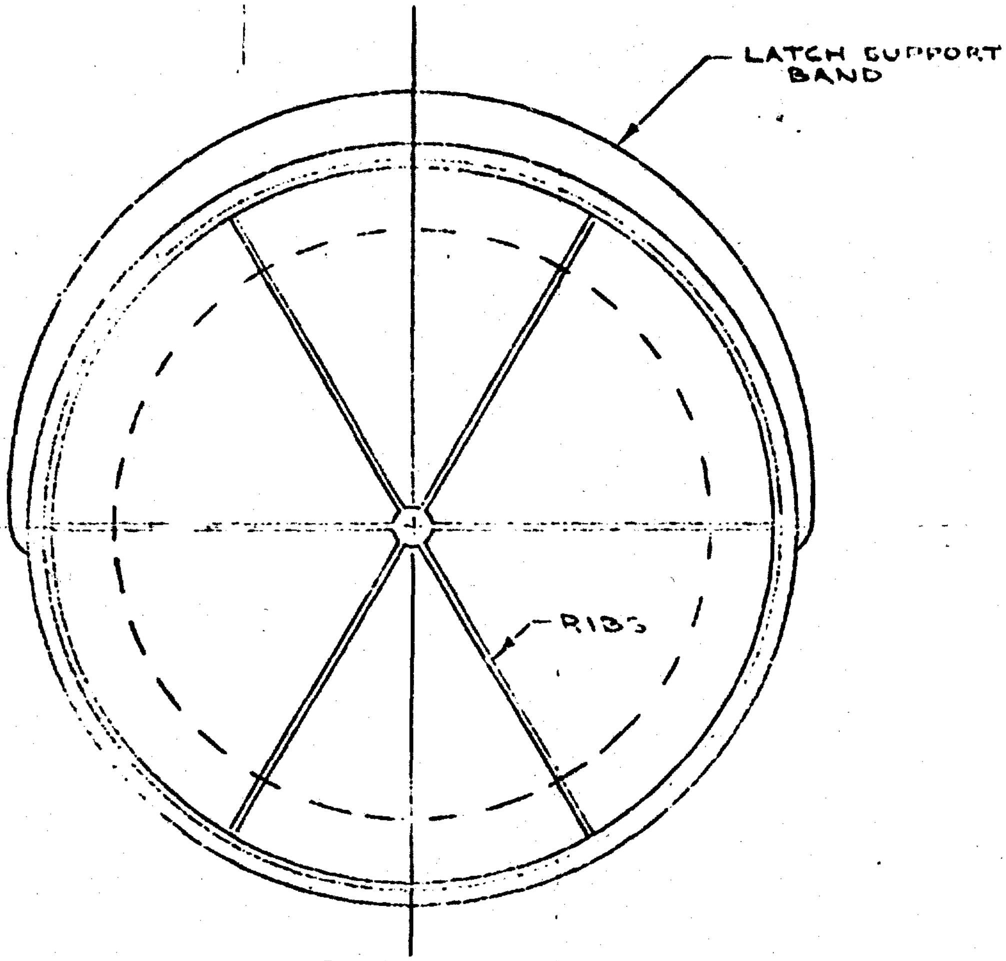


SECT D-D
(FWD CANISTER [illegible])
SCALE 3/4" = 1'-0"

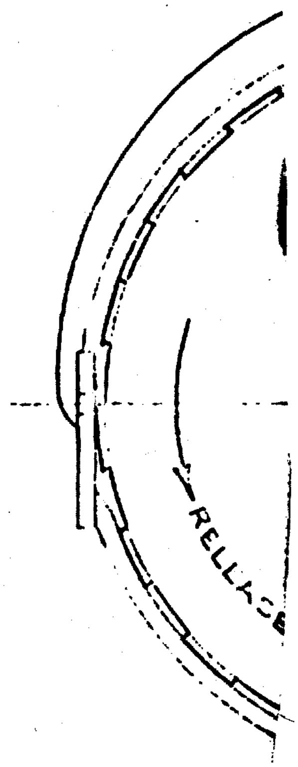


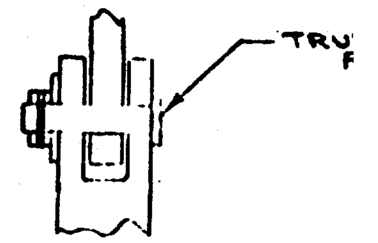
SECT C-C
RELEASE MECHANISM
SCALE $\frac{3}{4}$" = 1'-0"

NOTE:
1ST MOTION BREAKS LID LOOSE
ARM HITS STOP & CONTINUES
LID ROTATION TO RELEASE DOGS.

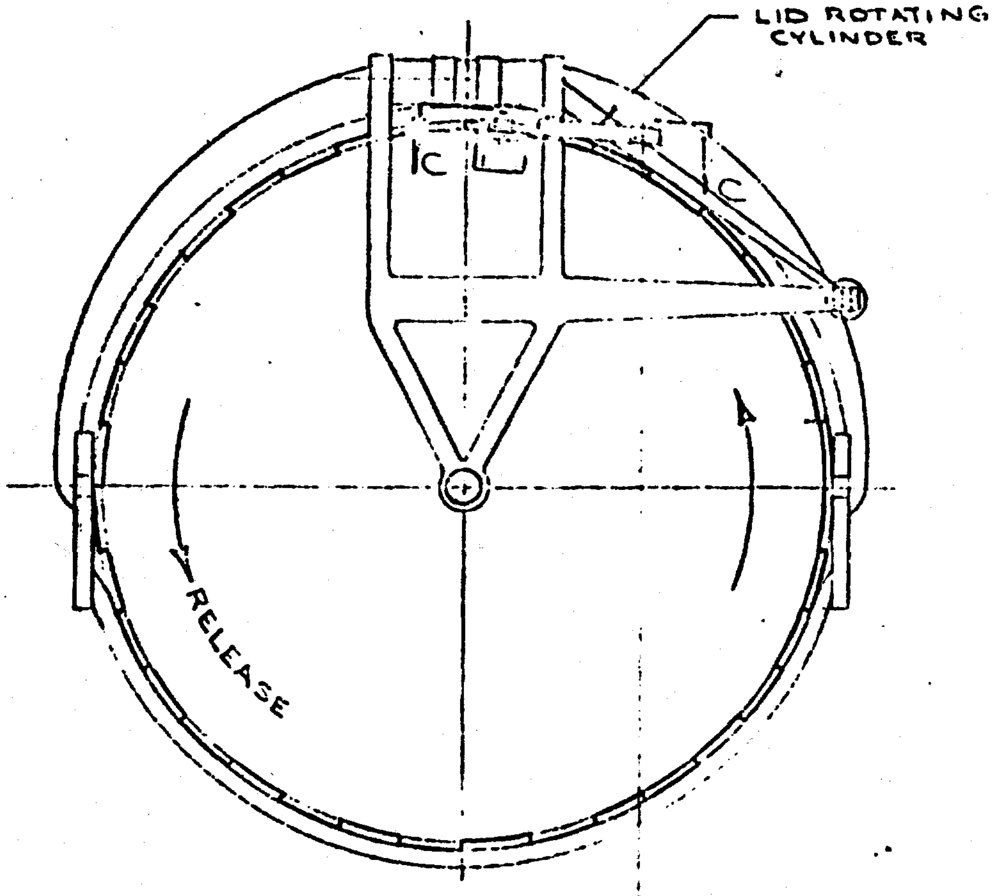


SECT B-B
INSIDE VIEW OF CANISTER BOTTOM

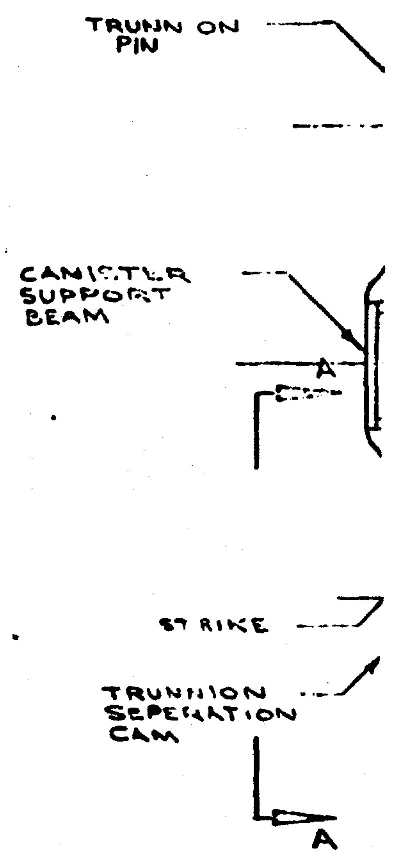


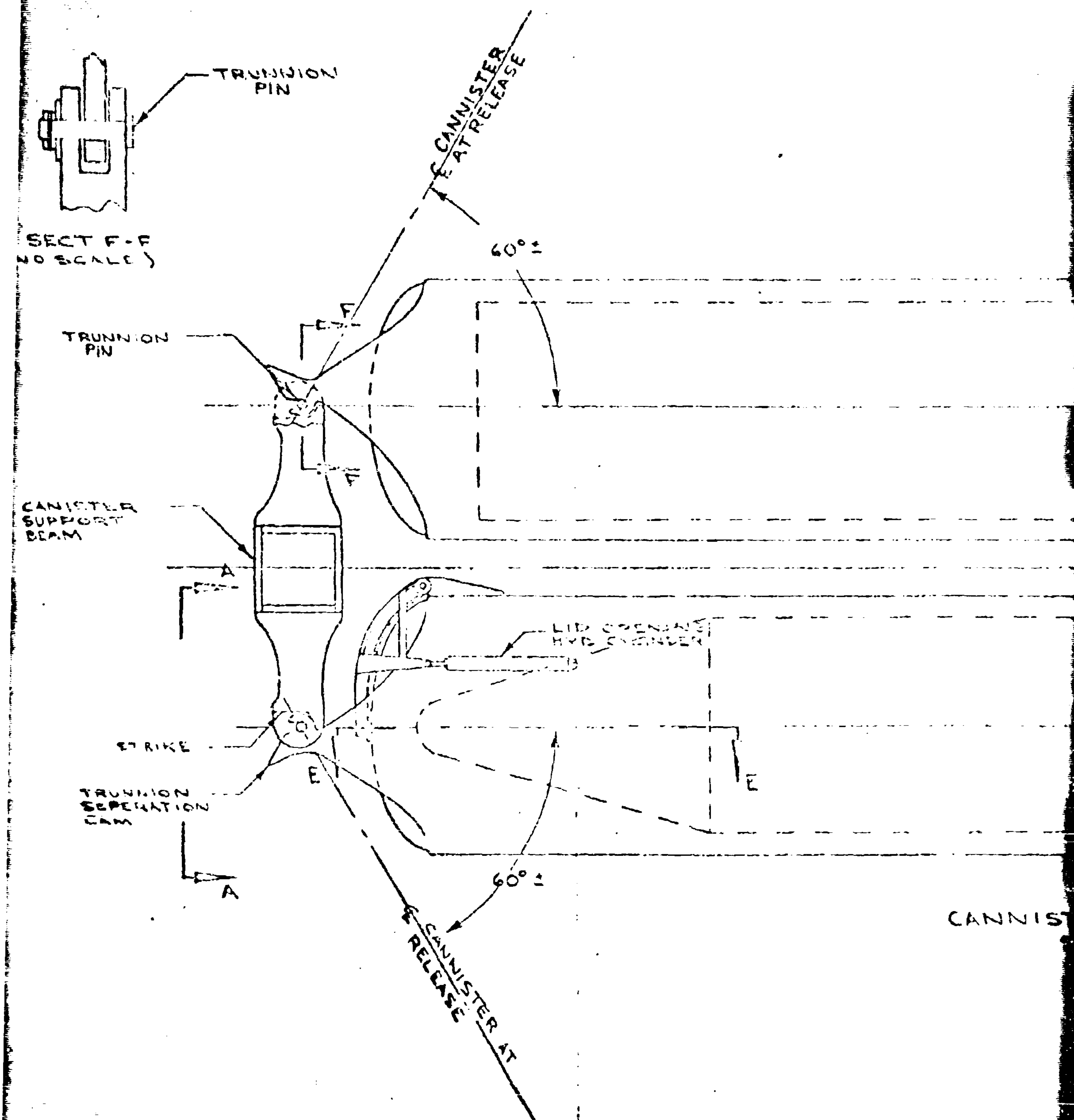


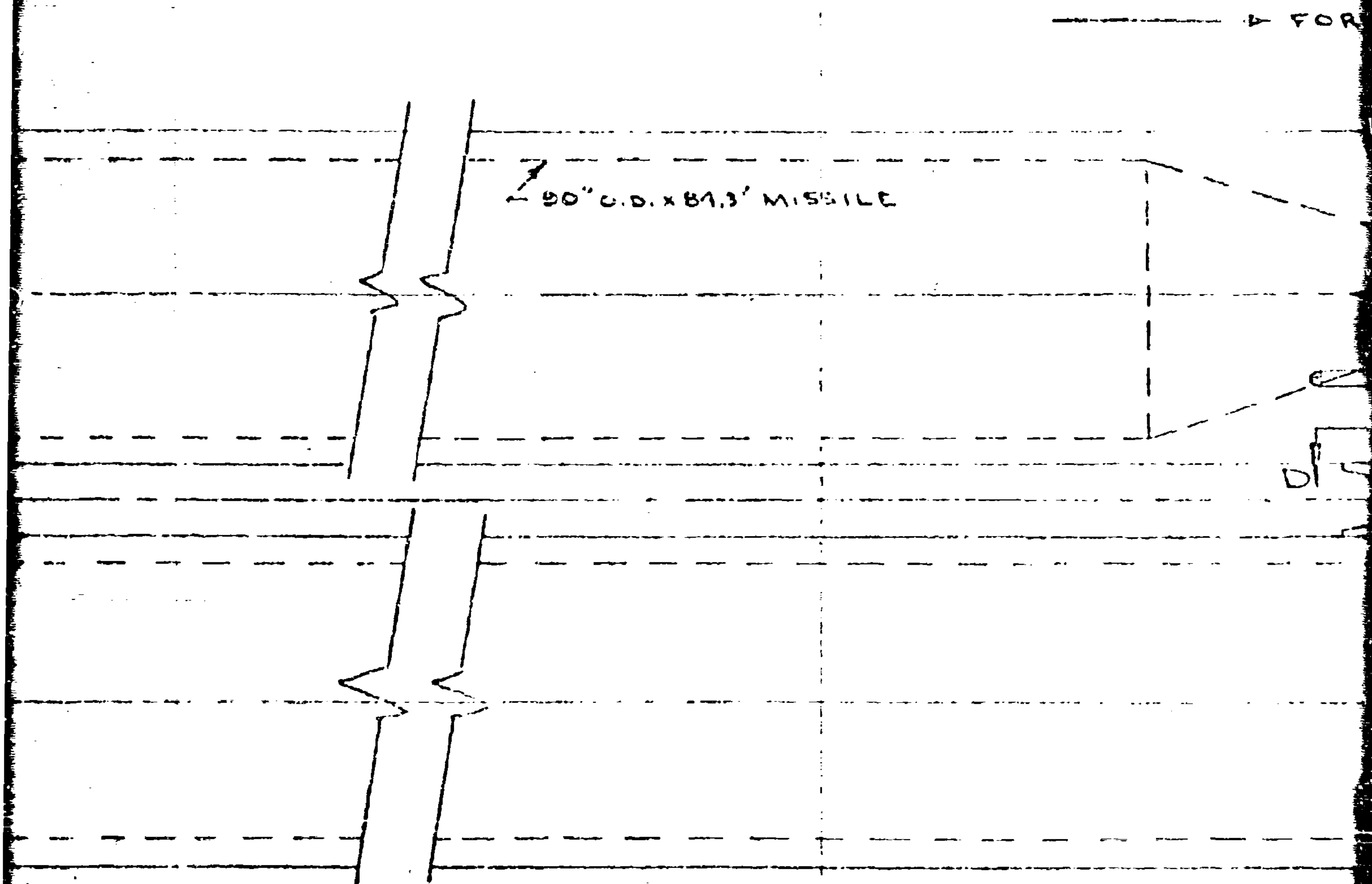
SECT F-F
(NO SCALE)



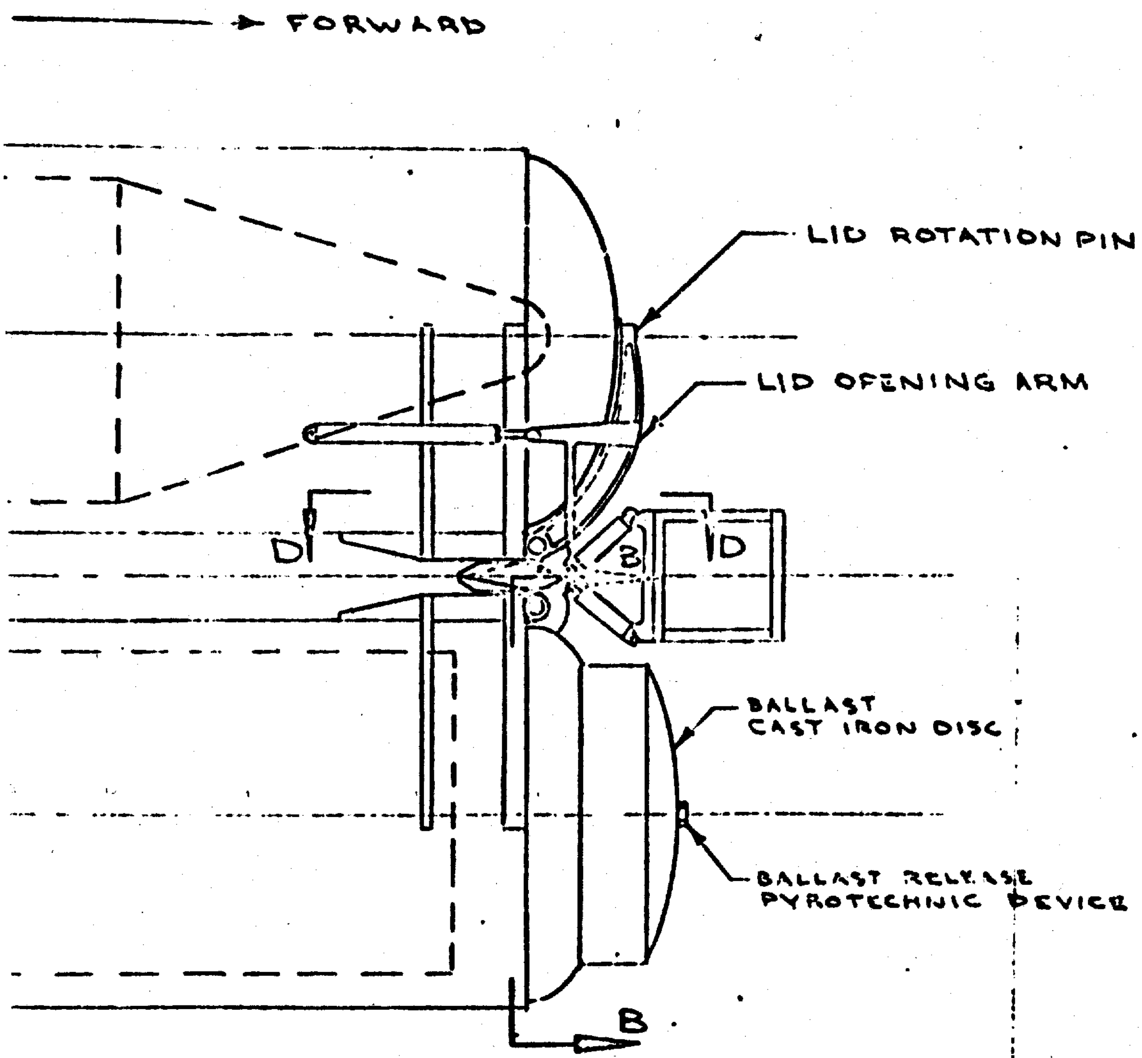
VIEW A-A
(PYLON NOT SHOWN)
SCALE $\frac{1}{2}$"=1'-0"




TRUNNION PIN
SECT F-F
NO SCALE)
CANNISTER
AT RELEASE
60° ±
TRUNNION PIN
F
F
CANISTER SUPPORT BEAM
A
A
LID OPENING HYD CYLINDER
STRIKE
TRUNNION SEPERATION CAM
E
E
60° ±
CANNISTER AT RELEASE
CANNIST



CANNISTER RELEASE MECHANISM
SCALE $\frac{1}{4}$" = 1'-0"



DESIGN ENGR.

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CANISTE
& RELEASE
SCALE NOTED

APPENDIX

SHEET 63

TION PIN

ARM

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ASE
DEVICE

THE BOEING COMPANY

CANISTER, SUSPENSION & RELEASE MECH. DETAILS

SCALE NOTED

APPENDIX A

SHEET: 63

DEFENSE LIMITED

			LAND [illegible]	
			BASE OPERATIONS	SHORT TE[RM] STORAG[E]
		REF. FUNCTION FIG. 3-1	3.2, 3.3, 3.4, 3.6, [illegible]	3.3, 3.5
		MAX. TIME REQD/CYCLE	30 DAYS	6 MONTH[S]
		MAX. CYCLES USEFUL LIFE	5	4
		LIMITS/ REMARKS	CONUS	CONUS
CONDITION	ENVIRONMENTAL FACTORS			
	[illegible]		16 5 A 5	16 [illegible] 4
HOT	WATER [illegible] (°F)		AVE. 85	NOT APPL[ICABLE]
	AIR TEMPERATURE [illegible]		80 [illegible]	[illegible] 110
	RADIATION ([illegible] FT²)		[illegible] 95	[illegible]
	% U.V. [illegible] A		[illegible] 6 6 6	
	% I.R. 7650 A		[illegible] 5[illegible]	
	WIND SPEED ([illegible])		7 7 7 7	6 [illegible] 6
THERMAL	CONTINUOUS [illegible]		20	6
	MAXIMUM NUMBER SUB CYCLES		1[illegible]	18
COLD	DURATION IN CYCLE (HOURS)		[illegible] 8 / 72	
	WATER TEMPERATURE (°F)		NOT APPLICABLE	N[OT APPLICABLE]
	AIR TEMPERATURE (°F)		-10 / -20	
	SKY TEMPERATURE (°F)		-30	
	WIND SPEED (KNOTS)		15	
	CONTINUOUS SUB CYCLES		20	6
	MAXIMUM NUMBER SUB CYCLES		1[illegible]	18

LAND OPERATIONS

...SE ...ATIONS	SHORT TERM STORAGE	TRANSPORT	LONG TERM STORAGE	SUSPENSION	SURFACED RELEASE	LA...
3.4.3.5, 3.20.1 THRU	3.3, 3.5	3.2	[illegible]	[illegible]	[illegible]	[illegible]
DAYS	6 MONTHS	2 MONTHS	[illegible]	[illegible]	[illegible]	[illegible]
	4	3	1	[illegible]		
...NUS	CONUS	CONUS	[illegible]	[illegible]		
4 | 5	[illegible] | 5	[illegible] | 5 | 4 | 5	5 YEARS	[illegible] | 4 | 5		
55	NOT APPLICABLE	NOT APPLICABLE		85	[illegible]	
110	[illegible] | 110	30 | 130	[illegible]	110		
95	[illegible]	0	[illegible]	95		
6 | 6				[illegible]		
[illegible] | 5?				[illegible]		
7 | 7	[illegible]	[illegible]	0	15		
20	6	10	1	25		
[illegible]	18	30	1	25		
72			5 YEARS	[illegible] | 4		
APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	28	26	
-20			-20	-45	[illegible]	
-30				-80	NOT APPLICABLE	N...
15			0	54 | [illegible] | 54	[illegible]	
20	6	10	1	25	1	
100	18	30	1	250	2	

DATA SHEET

2

SEA OPERATIONS

SURFACED						SUBMERGED		
[illegible]ASE	LAUNCH	RECOVERY				SUSPENSION	RELEASE	TRANSIT/*DWELL
	3.11	3.12, 3.12.1				3.8, [illegible]	3.10	3.10.1, 3.10.2
[illegible]S	5 SECONDS	60 DAYS				81 DAYS	3 [illegible]	2[illegible] / 90 MIN
	2	2				33	2	2 / [illegible]
[illegible]								
		10	5	4	5	EQUIVALENT	NEGLIGIBLE	.05/1.5
5	85	84	↗	85	↘	80	85	85
0	12[illegible]	85	↗	110	↘	Not Applicable	Not Applicable	Not A[illegible]
)	0	0	↗	95	↘			"
)	0	0	6	6	6	"		"
)	0	0	50	50	50	"	"	
0	20	20	20	20	20	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
	1	20				1	1	1
2	2	40				33	2	2
	--	10	5	4	5	EQUIVALENT	NEGLIGIBLE	.05/1.5
6	26	28	↘	26	↗	26	26	2[illegible]
6	-20	10	↘	-20	↗	Not Applicable	Not Applicable	Not Applicable
APPLICABLE	Not Applicable	-30	↘	-40	↗	Not Applicable	Not Applicable	Not Applicable
6	26	20	20	20	20	Not Applicable	Not Applicable	Not Applicable
1	1	1				1	1	1
2	2	2				33	2	2

DEFENSE LIMITED

Calc	W.H.H	7-9	REVISED	DATE	ULMS CANISTER DESIGN NATURAL ENVIRONMENT THERMAL	APPENDIX B
Tr						
Ch	W.H.H	12-69				
App					THE BOEING COMPANY SEATTLE, WASHINGTON 98124	SHEET 64
App						

DEFENSE LIMITED

		LAND OPE					
		BASE OPERATIONS				SHORT TERM STORAGE	
	REF. FUNCTION FIG. 3-1	3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.20.1 incl 3.20.7				3.3, 3.5	
	MAX. TIME REQ'D/CYCLE	30 DAYS				6 MONTHS	
	MAX. CYCLES USEFUL LIFE	5				4	
	LIMITS/ REMARKS					CONUS	
CONDITION	ENVIRONMENTAL FACTORS						
HIGH	DURATION IN CYCLES (HOURS)	10	4	10		SAME AS	
	ABS HUMIDITY (GRAINS/FT 3)	11 ↗	13	↘		BASE OPERATION	E
	DEW POINT (°F)	80 ↗	85	↘			
	CONTINUOUS SUB-CYCLES	3				6	
	TOTAL NUMBER SUBCYCLES	15				24	
HUMIDITY	DURATION IN CYCLE (HOURS)	[illegible]	4			SAME AS	
	RELATIVE HUMIDITY (%	93-97	100% AND			BASE OPERATION	
	AIR TEMPERATURE (°F)		75-80				
	RADIATION AND WIND SPEED (KTS)	0	0				
		–					
	CONTINUOUS SUB-CYCLES	3				6	
	TOTAL NUMBER SUB-CYCLES	15				24	
LOW	DURATION IN CYCLES (HOURS)	72				SAME AS	
	ABS HUMIDITY (GRAINS/FT 3)	0.01				BASE OPERATION	
	DEW POINT (°F)	-65					
	CONTINUOUS SUB-CYCLES	3				6	
	TOTAL NUMBER SUB-CYCLES	15				24	
	DURATION IN CYCLES (HOURS)	10	5	4	5	SAME AS	
	RELATIVE HUMIDITY	15	↘	5	↗	BASE OPERATION	
	AIR TEMPERATURE (°F)	85	↗	105	↘		
	RADIATION AND WINDSPEED (KTS)	0	0	0	0		
	CONTINUOUS CYCLES	3				6	
	TOTAL NUMBER OF CYCLES	15				24	

↘ = DECREASE, ↗ = INCREASE AT UNIFORM RATE FROM PRECEDING TO FOLLOWING OR ORIGINAL CONDIT

AND OPERATIONS

SHORT TERM STORAGE	TRANSPORT	LONG TERM STORAGE	SURFACED SUSPENSION		SURFACED RELEASE	SURFACED LAUNCH
3.3, 3.5	3.2	3.2, 3.3	3.7, 3.8, 3.9, 3.20.1 3.20.2, 3.20.3		3.10	3.11
6 MONTHS	2 MONTHS	5 YEARS	25 DAYS		3 [illegible]	5 SEC
4	3	1	33		2	2
CONUS						WORLDWIDE
SAME AS BASE OPERATION	SAME AS BASE OPERATION		10 4 10 11↗ 13↘ 8↗ 85↘		NOT APPLICABLE	NEGLIGIBLE
6 24	2 6		10 330			
SAME AS BASE OPERATION	SAME AS BASE OPERATION	5 YEARS 90 -20 TO 115 0	20 93-97 80-95 0	4 100 %/COND 75-8[illegible] 0	NOT APPLICABLE	NEGLIGIBLE
6 24	2 6	1 1	3 100			
SAME AS BASE OPERATION	SAME AS BASE OPERATION		72 0.01 -65		NOT APPLICABLE	NEGLIGIBLE
6 124	2 6		1 33			
SAME AS BASE OPERATION	10 5 4 5 15 ↘ 2 ↗ 90 ↗ 140 ↘ 0 0 0 0	5 YEARS 0 -20 TO 115	↘ 5 ↗ ↗ ↘ 50 - 15KTS		NOT APPLICABLE	NEGLIGIBLE
6 24	2 6	1 1	5 165			

ORM RATE
RIGINAL CONDITION

NOTE: THE VALUES SHOWN ARE PRELIMINARY. VERIFICATION OR CORRECTION IS REQUIRED FOR CONTRACT DEFINITION

DATA SHEET

DEFENSE LIMITED

SEA OPERATIONS

	SURFACED LAUNCH	RECOVERY	SUBMERGED SUSPENSION	RELEASE	TRANSIT/* DWELL
	3.[illegible]	3.[illegible], 3.[illegible]	3.8 [illegible]	[illegible]	[illegible]
	5 SEC	60 DAYS	81 DAYS	2 [illegible]	[illegible]
	2	2	[illegible]	[illegible]	[illegible]
	WORLDWIDE	DEPLOYMENT			
	NE[illegible]	SAME A[illegible] S[illegible]	NOT APPLICABLE		
		20 / 40			
	NEGLIGIBLE	20 / 93-97 / 81-85 / 7 — 4 / [illegible] / [illegible] / 3			
		3 / 6			
[illegible]BLE	NEGLIGIBLE	280			
		1 / 2			
[illegible]	NEGLIGIBLE	10 / 15 / 30 — 5 — 4 / 2 / 50 — 5			
		50 - 15 KTS			
		10			
		20	NOT APPLICABLE		

[illegible]ARY. [illegible]NITION	Calc	W.H.H	7-[illegible]	REVISED	DATE
	Tree				
	Chk	W.H.H	[illegible]		
	Appd				
[illegible]NSE LIMITED	Appd				

ULMS CANISTER DESIGN
NATURAL ENVIRONMENT
HUMIDITY

APPENDIX B
SHEET 65

THE BOEING COMPANY
SEATTLE, WASHINGTON 98124

DEFENSE LIMITED

		LAN...	
		BASE OPERATIONS	SHOR... ST...
	REF. FUNCTION FIG 3-1	3.2, 3.3, 3.4, 3.5 [illegible] 3.20.1 thru 3.20.7	3.[illegible]
	MAX. TIME REQD/CYCLE	30 DA[illegible]	[illegible]
	MAX. CYCLES/ USEFUL LIFE	5	4
	LIMITS/ REMARKS	/	
CONDITION	ENVIRONMENTAL FACTORS		
	CYCLE:		
WIND (10 FEET ABOVE SURFACE)	STEADY FLOW (KNOTS)	70	7[illegible]
	GUSTS, INSTANTANEOUS (KNOTS)	[illegible]	[illegible]
	NUMBER OF [illegible] CYCLES	[illegible]	[illegible]
SEA	STATE / DESCRIPTION	3/	[illegible]
	WAVE HEIGHT (AVE/SIGNIF/ 1/10 HIGHEST		
	SIGNIF RANGE OF PERIODS (SEC)		
	PERIOD OF MAX ENERGY (SEC)		
	AVERAGE PERIOD $\bar{T}$ (SEC)		
	AVERAGE WAVE LENGTH (FT		
	MINIMUM DURATION (HOURS)		
	DESIGN WALL FORCE (PSI) STATIC +DYN		/
	CURRENT (MAX. KTS)		/
ICE	MAX. SOLID THICKNESS (FEET)		/
	SINGLE POINT BREAKING PRESSURE (LBS)		
	PACK ICE AVE. MASS/UNIT (LBS)		
PENETRATION & ABRASION SNOW	SNOW CRYSTALS DIA. (MM)	1 To 3	SAME A...
	WIND SPEED (KNOTS)	35	[illegible]
	AIR TEMPERATURE (°F)	26	
SAND	GRAIN DIAMETERS (MM)	0.01 To 1.0	SAME A...
	PREDOMINANT DIA (MM)	0.15 To 0.30	OPERAT...
	VELOCITY (FEET/SEC)	35	
	AMBIENT TEMPERATURE (°F)	70	

	LAND OPERATIONS					SURFACE	
BASE OPERATIONS	SHORT TERM STORAGE	TRANSPORT	LONG TERM STORAGE	SUSPENSION	RELEASE	LA
3.3.4, 3.5 3.3.20.1 THRU	3.3, 3.5	3.2	3.2, 3.3	[illegible]	3.10	
DAYS	[illegible]	MONTHS	5 YEARS	25 DAYS	3 SECONDS	5 S
5	4	3	1	33	2	
	CONUS					WORL
70	70	70	70	70	NOT	7
105	105	105	105	105	APPLICABLE	
30	15	10	30	30	—	
	NOT APPLICABLE			[illegible]	[illegible]	6
				44 [illegible]	[illegible]	7
				[illegible]	4 - 14 [illegible]	4
				15	10	
				15.8	7.4	
				650	15	
				67	7	
IC N				50		
	NOT APPLICABLE			10	[illegible]	
				[illegible]	1.5	
RE(LBS)	NOT APPLICABLE			75 [illegible]	75 [illegible]	7
S)				75 [illegible]	7 [illegible]	7
1 To 3	SAME AS BASE	SAME AS BASE	SAME AS BASE	1 TO 3	NOT	
35	OPERATIONS	OPERATIONS	OPERATIONS	55	APPLICABLE	
26				-65		
.01 To 1.0	SAME AS BASE	SAME AS BASE	SAME AS BASE	NOT APPLICABLE		
To 0.30	OPERATIONS	OPERATIONS	OPERATIONS			
35						
70					NOT APPLICABLE	

DEFENSE LIMIT

DATA SHEET

SEA OPERATIONS

SURFACED			SUBMERGED		
[illegible]SE	LAUNCH	RECOVERY	SUSPENSION	RELEASE	TRANSIT/*DWELL
	3.11	3.12, 3.12.1	3.8.[illegible]	3.10	3.[illegible]
[illegible]NDS	5 SECONDS	60 DAYS	81 DAYS	5 SECONDS	2MIN/[illegible]
	2	2	33	2	2/2
	WORLDWIDE DEPLOYMENT				
	24	24	NOT APPLICABLE		
[illegible]ABLE	47	26			
	1	[illegible]			
[illegible]	6/[illegible]	5/Stone Bed	9/[illegible]	6/[illegible]	6/[illegible]
[illegible]	96/15/28	93/[illegible]/16	44/71/20	96/15/28	9[illegible]/57/[illegible]
[illegible]	4.9-14	3.7-13.5	7.5-26	4.9-14.5	4.[illegible]
	16.5	9.7	13.4	16.5	16.5
	7.4	6.8	13.[illegible]	7.4	7.4
	1[illegible]	1[illegible]	[illegible]	1[illegible]	128
	17	14	62	17	17
	16	15	50	16	16
	4	4	16	4	4
	1.5	1.5	[illegible]	1.5	1.5
	7500	7500	7500	7500	7500
	7500	7500	7500	7500	7500
	1 TO 3	1 TO 3	NOT APPLICABLE		
[illegible]ABLE	40	36			
	-65	-70			
[illegible]ABLE				NOT APPLICABLE	
[illegible]APPLICABLE				NOT APPLICABLE	

Calc	W.H.H	1-9	REVISED	DATE	ULMS CANISTER DESIGN	
Trac						APPENDIX B
Chk	W.H.H	12-9[illegible]			THE BOEING COMPANY SEATTLE, WASHINGTON 98124	SHEET 6
Appr						
Appr						

[illegible]SE LIMITED

DEFENSE LIMITED

		LAND OPER[...]		
		BASE OPERATIONS	SHORT TERM STORAGE	T[...]
	REF. FUNCTION FIG 3-I	3.2, 3.3, 3.4, 3.5, 3.6 [illegible] 1.3.20.1 THRU 3.20.[illegible]	[illegible]	
	MAX. TIME REQD/CYCLE	30 DAYS	[illegible]	
	MAX. CYCLES/ USEFUL LIFE	[illegible]	4	
	LIMITS/ REMARKS	[illegible]	[illegible]	
CONDITION	ENVIRONMENTAL FACTORS			
DUST PENETRATION AND ABRASION	GRAIN DIAMETER (MM)	.0001 TO 0.01	SAME AS BASE OPERATIONS	SA[...]
	DENSITY (gm/ft3)	.1 TO .5		2[...]
	VELOCITY	4[illegible]		
	AMBIENT TEMP. (°F)	70		
	DURATION IN SUBCYCLES (HRS)	50	SAME AS BASE OPERATIONS	SA[...] O[...]
	SALT SOLUTION (%)	[illegible]		
	DENSITY ([illegible]/IN/CM2)	.0004 T[illegible]		
	TEMPERATURE	[illegible]5		
	CONTINUOUS SUBCYCLES	1		
	TOTAL NUMBER SUBCYCLES	1		
FOULING	DURATION CONTINUOUS EXPOSURE	NOT APPLICABLE	NOT APPLICABLE	NOT[...]
	MAX TIME BETWEEN CLEANINGS			
	GROWTH (LBS/FT2)			
	COF (WORST CASE)			

LAND OPERATIONS

SHORT TERM STORAGE	TRANSPORT	LONG TERM STORAGE	SUSPENSION	SURFACED RELEASE	LAUNCH
3.3, 3.5	3.2	3.2, 3.3	3.7, 3.8, 3.9, 3.20.1, 3.20.2, 3.20.3	3.10	3.11
6 MONTHS	2 MONTHS	5 YEARS	25 DAYS	3 SEC.	5 SEC.
4	3	1	33	2	2
CONUS →					WORLDWIDE
Same As Base Operations	Same As Base Operations	Same As Base Operations	Same As Base Operations	Not Applicable	Not Applicable
Same As Base Operations	Same As Base Operations	Same As Base Operations	Same As Base Operations	Negligible	Negligible
Not Applicable	Not Applicable	Not Applicable	7 MONTHS →		
			24 MONTHS →		
			10	10	10
			0.0019	0.0019	0.0019

DEFENSE LIMITED

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SEA OPERATIONS

URFACED			SUBMERGED		
SE	LAUNCH	RECOVERY	SUSPENSION	RELEASE	TRANSIT/*DWELL
	3.11	3.12, 3.12.1	3.9, 3.9	3.10	3.10.1, 3.10.2
E.	5 SEC	60 DAYS	81 DAYS	3 SEC	21 MIN/30 [illegible]
	2	2	35	2	2/2
	WORLDWIDE DEPLOYMENT				
CABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
BLE	NEGLIGIBLE		NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
			7 MONTHS		
			24 MONTHS		
	10	10	10	10	
9	0.0019	0.003	0.0019	0.0019	0.0019

SE LIMITED

Calc.	W.H.H.	8-9	REVISED	DATE	ULMS CANISTER DESIGN NATURAL ENVIRONMENT PENETRATION, ABRASION, SALT, FOULING	APPENDIX B
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Chk	W.H.H.	8-9			THE BOEING COMPANY SEATTLE, WASHINGTON 98124	SHEET 67
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DE[illegible]		BASE OPERATIONS	LAN[illegible] SHOR[illegible] STO[illegible]
	REF. FUNCTION FIG. 3-1	[illegible] 3.7.3.[illegible] THRU 3.[illegible]	
	MAX TIME REQ'D/CYCLE	[illegible]0 DA[illegible]	[illegible]
	MAX. CYCLES/ USEFUL LIFE	5	[illegible]
	LIMITS/ REMARKS		

CONDITION	ENVIRONMENTAL FACTORS					
	DURATION/CYCLE (HRS MIN)	11:55	0:[illegible]5	11:[illegible]	1:[illegible]	SAME A[illegible]
RAIN	AMOUNT (INCHES)	12	2	11	7	
	DROP DIA. (MEAN MM)	[illegible]5	4.[illegible]	2.[illegible]	3.[illegible]	
	(STD DEV MM)	.77	1.[illegible]8	.77	[illegible]	
	AIR & WATER TEMPERATURE (°F)	7[illegible]	[illegible]	7[illegible]	7[illegible]	
	WIND SPEED (KNOTS)			25		
	CONTINUOUS SUB-CYCLES	1				
	TOTAL NUMBER SUB-C[illegible]	5				
	DURATION/CYCLE (HRS: MIN)	1:[illegible]	[illegible]:15	1:[illegible]	[illegible]	SAME A[illegible]
	AMOUNT (INCHES)	1.0	0.8	1.0	[illegible]	OPERAT[illegible]
	DROP DIAMETER (MEAN MM)	2.0	2.0	2.0	—	
	AIR AND WATER TEMP (°F)	28				
	WIND SPEED (KNOTS)	15				
	CONTINUOUS SUB-CYCLES	1				
	TOTAL NUMBER SUB-CYCLES	5				
	SNOW LOAD (LBS/FT²)	20				SAME A[illegible]
SNOW	TOTAL NUMBER OF DAYS	15				OPERAT[illegible]
AIR	MAXIMUM STATIC (PSI)	15.4				15.[illegible]
	MAXIMUM STATIC (PSI)	14.0				14
PRESSURE	MAXIMUM DYNAMIC (PSF)	30				3[illegible]
WATER	MAXIMUM STATIC (PSIG)	—				NOT[illegible]
	MAXIMUM DYNAMIC (PSI)					—

...SE OPERATIONS		LAND OPERATIONS: SHORT TERM STORAGE	TRANSPORT	LONG TERM STORAGE	SUSPENSION				SURFACED: RELEASE	LA...
...4,3.5,3.6, THRU 3.20.7		3.3, 3.5	3.2	3.2, 3.3	3.7, 3.8, 3.9, 3.20.1, 3.20.2, 3.20.3				3.10	3.11
...AYS		6 MONTHS	2 MONTHS	5 YEARS	25 DAYS				3 SECONDS	5 SE...
		4	3	1	33				2	[illegible]
[illegible]		CONUS			[illegible]				WORLDWIDE	
11:00	1.0	SAME AS BASE OPERATIONS	SAME AS BASE OPERATIONS	[illegible]	[illegible]				NEGLIGIBLE	NEG...
11	7									
2.0	3.2									
.77	1.1									
70	70									
35										
		1	1	1	3					
		4	3	5	[illegible]					
11:30	20:30	SAME AS BASE OPERATIONS	SAME AS BASE OPERATIONS	SAME AS BASE OPERATIONS	11:30	0:30	11:30	21:30	NEGLIGIBLE	NEGL...
1.0	6				1.0	1.0	1.0	0		
2.0	—				2.0	2.0	2.0	—		
					28/28					
					20					
					1					
					33					
		SAME AS BASE OPERATIONS	SAME AS BASE OPERATIONS	NOT APPLICABLE	20				0	
					25				1	
		15.4	15.4	15.4	15.4				15.4	1...
		14.0	11.3	14.0	14.0				14.0	1...
		30	45	30	45				0	[illegible]
NOT APPLICABLE					12				52	[illegible]
					+50				6	

DEFENSE LIMITE...

DATA SHEET

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SEA OPERATIONS

	SURFACED LAUNCH	RECOVERY	SUSPENSION	SUBMERGED RELEASE	TRANSIT/*DWELL
	3.11	3.12, 3.12.1	3.8, 3.9	3.10	3.10.1, 3.10.2
	5 SECONDS	60 DAYS	81 DAYS	3 SECONDS	2 MIN / 30 MIN
	2	2	[illegible]	2	2/2
	WORLDWIDE DEPLOYMENT				
	NEGLIGIBLE	SAME AS BASE OPERATIONS	←	NOT APPLICABLE	→
		7			
		6			
	NEGLIGIBLE				
		28/28			
		20			
		1			
		2			
	0	10			
		20			
	15.1	15.4			
	14.0	14.0			
	20	30	←	NOT APPLICABLE	→
	40	4	311	350	467/325
	6	6	+36	+6	+6/+6

			REVISED	DATE	
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APPENDIX B

SHEET 6A

DEFENSE LIGHT [illegible]

		LAND				
		BASE OPERATIONS			SHORT T[illegible] STORA[illegible]	
	REF. FUNCTION FIG 3-1	3.2 [illegible] 4, [illegible] [illegible] 20.1 THRU 3.20.[illegible]			3.[illegible]	
	MAX. TIME REQ'D/CYCLE	30 DA[illegible]			MONT[illegible]	
	MAX. CYCLES/ USEFUL LIFE					
	LIMITS/ REMARKS					
CONDITION	ENVIRONMENTAL FACTORS					
		Nx	Ny	Nz	N[illegible]	N[illegible]
MECHANICAL	MAX "G" LOADS TRANSPORTATION & HANDLING	±1.33	±1.0	±1.33	0	0
SHOCK	DURATION - MILLISECONDS	0-40	0-40	0-40	-	-
	PULSE SHAPE REF FIG 516-9 OF MIL STD 810					
VIBRATION	DISPL DOUBLE AMPL (NOT ESTABLISHED)					
ACOUSTIC	(NOT ESTABLISHED)					
WEAPON EFFECT	SHOCK MAX. G LOADS OVERPRESSURE (PSI)	NOT APPLICABLE			NOT APPLI[illegible]	
MANEUVERING & RESISTANCE FORCES REF 2, APP B	AXIAL DRAG FORCE (Fa) $= 2.85\,C_A S_0 V^2 \cos^2 h + F_D C [illegible] - F_L \sin [illegible]$ NORMAL FORCE (Fn) $= 2.85\,C_N S' V^2 \sin^2 \alpha_h$	NOT APPLICABLE			NOT APPL[illegible]	

+Nx : FORWARD
+Ny : LEFT
+Nz : DOWN

GD-4011-4000 REV 12/62

LAND OPERATIONS

...IONS	SHORT TERM STORAGE	TRANSPORT	LONG TERM STORAGE	SUSPENSION	RELEASE	LAUN...
				SURFACED		
3.5 ...0.1 THRU	3 3,3.5	3.2	3.2,3.3	3.7, 3.8, 3.9, 3.20.1, 3.20.2, 3.20.3	3.10	3.11
...YS	6 MONTHS	2 MONTHS	5 YEARS	25 DAYS	3 SEC.	5 S...
	4	3	1	33	3 SEC	2
	CONUS					WORLD...

Nz	Nx	Ny	Nz	Nx	Ny	Nz	Nx	Ny	Nz	Nx	Ny	Nz	Nx	Ny	Nz	Nx	N...
±1.33	0	0	±1.5	±3.0	±1.5	+20	0	0	±1.5	±2.0	±1.5	±1.33	±1.33	±1.33	±1.33	0	0
0-40	—	—	0-40		0-40	10-50	-	-	0-40	40	40	40	0-40	0-40	0-40	-	-

...ABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	±3.0 ±3.0 ±3.0		...
				151	151	0
...CABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT ESTABLISHED		

DEFENSE ...

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SEA OPERATIONS

[illegible]																
SURFACED										SUBMERGED						
E	LAUNCH			RECOVERY			SUSPENSION			RELEASE			TRANSIT/*DWELL			
	3.11			3.12, 3.12.1			3.3, 3.9			3.10			3.10.1, 3.10.2			
	5 SEC			60 DAYS			81 DAYS			3 SEC			2 MIN / 3 MIN			
	2			2			33			2			2/2			
	WORLDWIDE DEPLOYMENT															
N_z	N_x	N_y	N_z	N_x	N_y	N_z	N_x	N_y	N_z	N_x	N_y	N_z	N_x	N_y	N_z	
±1.33	0	0	±1.50	±1.5	±1.5	+1.5	±2.0	±1.5	±1.33	±1.33	±1.33	±1.33	[illegible]	[illegible]	[illegible]	
0-40	–	–	0-40	0-40	0-40	0-40	40	40	40	40	40	40	8	8	8	
	6			NOT APPLICABLE			±3.0	±3.0	±3.0	–			±3.0	±3.0	±3.0	
	0						151			–			151			
ESTABLISHED										NOT ESTABLISHED						

CALC	W.U.H.	12-73	REVISED	DATE	ULMS CANISTER DESIGN	
CHK	W.U.H.	12-5-73				APPENDIX E
APP					THE BOEING COMPANY SEATTLE, WASHINGTON 98124	SHEET 69
APP						

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